MILK PRODUCTION DURING FIRST LACTATION COUPLED WITH AGE AT FIRST CALVING AS A MEASURE OF PREDICTING LIFETIME PRODUCTION IN RED SINDHI AND RED SINDHI CROSSBRED CATTLE IN INDIA

by

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INTRODUCTION

Indian Cattle Problem

Agricultural Practices. India is an agricultural country where more than 75 per cent of the population are farmers. Yet, paradoxical as it may seem, advances in agriculture have been neglected. To an average farmer agriculture is a way of life, not a business. For this reason agriculture has not improved to as great an extent as have other enterprises in India during recent years. For the most part, agricultural operations today are little different from what they have been for generations in the past.

The large number of people depending upon agriculture for their occupation and the relatively small amount of arable land result in small holdings per farmer, an average of 2.5 acres. This, in itself, is too small for profitable farming, and in addition, the current laws of inheritance of property cause these small holdings to be distributed in fragments. Thus farming is an occupation run on a very small, uneconomical scale. These conditions, plus other factors, have prevented and probably will prevent for some time to come, the introduction of mechanized farming.

The climatic conditions are quite variable in India, affecting agricultural practices in the different parts of the country. The northern part of the country covers the Indo-gangetic plain subjected to the intense heat of the summer and the humid, monsoon season of July

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[1] The population of India according to the 1951 census was 360 million.

to September, followed by a mild winter. The average annual rainfall varies from 20 to 50 inches, most of which is received during the monsoon. Sorghum, corn, rice and millets are grown during the monsoon, and wheat, barley, oats, etc. are grown during the winter. Very little vegetation grows during the summer heat from April to June. Southern and eastern India receive more rainfall varying from 50 to 80 inches per year, and in each season rice is the main crop grown. In certain areas of southern and eastern India, cultivation is possible only under water.

The power for cultivation is provided almost entirely by cattle. The castrate male of Indian cattle called "bullock" is the Indian tractor. A pair of bullocks yoked to a plough, cultivator or a crude seed drill provide the necessary draft power. A pair of bullocks will, on the average, plough about three fourth of an acre in an eight hour day. The most common vehicle of transportation in the villages is the two-wheeled cart drawn by a pair of bullocks. On the average, a cart will haul about half a ton, and will maintain a speed of two to three miles per hour on common dirt roads. Bullocks are used for drawing water from wells, crushing oil cake to extract oil, crushing sugar cane, threshing harvested grains, etc. In some parts of India, buffalo males are used for agricultural operations.

Dairy Cattle. In addition to power for agriculture, Indian cattle provide milk for human consumption. In the villages the milk produced is used for home consumption, and the surplus is converted to ghee (butter oil). Fluid milk trade exists to a measurable extent only in the villages around the urban areas. In most parts of the country,

where fluid milk trade exists, great numbers of buffaloes are kept. For generations Indian cattle called Zebu (Tibetan word meaning humped) have been developed for work, and buffaloes for milk. In the villages male calves born to Zebu cows are well cared for, whereas female calves are neglected and great numbers of them die. On the other hand, the buffalo male calf is neglected in comparison with the female calf. Several reasons have led to the development of Zebu for work and buffalo for milk. Due to the tremendous population and limited land resources, there is a constant competition between man and cattle for food. The food of better quality obviously goes to man. Grains of inferior quality and by-products that are not consumed by man become the feed for cattle. Thus it becomes necessary for cattle and buffaloes to depend on food of low quality for their nutrition. Milk production calls for higher quality of food. The author has heard it expressed by villagers that the buffalo converts coarse food more efficiently than the cow. Buffalo milk is high in fat content and since the main medium through which milk is consumed in India is ghee, the buffalo with the ability to produce higher fat content milk is considered better. Zebu, on the other hand, are more active and work faster than the buffaloes, particularly during the warm weather.

Cattle Population. Though this development of cattle and buffaloes for specific purposes can be commended under the conditions that existed, it has resulted in the greatest problem of the cattle industry in India, the problem of too many cattle. There are about 176 million cattle in India, which is one quarter of the world's cattle population. The human population is about one sixth of the world's population. The 176 million

are composed of 136 million Zebu cattle and 40 million buffaloes. Out of these about 40 million Zebu cows and 20 million buffalo cows are over three years of age (Brochure of the marketing of milk in Indian Union, 1950).

The tremendous number of cattle have resulted in insufficient food. The productive as well as the unproductive cattle have shared the available food, causing the progressive deterioration of the few productive animals. Useless cattle need to be removed so as to offer better environment and feed for the productive cattle to do their best. The sentimental and orthodox religious objections of most people to the slaughter of useless cattle has made the problem a difficult one to solve. Education and a progressive approach to economic problems are enabling people to take a more realistic approach to the slaughter of useless cattle. Meanwhile, efforts are being made to dispose of useless cattle in other ways. In most States scrub bulls are castrated by the veterinarian or extension workers to prevent indiscriminate breeding. Most States are distributing breeding sires to the villages for natural and artificial service to improve their cattle. A few States have resorted to transfer of useless cattle from the villages to "concentration camps" in forests and hills where they are encouraged to die a natural death.

The total milk production in India is about 40 billion pounds a year. The buffaloes produce about 55 per cent of the total production. The average annual milk production per cow is 413 pounds, and the average production per buffalo is 1101 pounds. The estimated production per cow and buffalo, after allowing a margin for the milk sucked by the

calf is 525 pounds and 1250 pounds respectively.[1] The total milk production in India is about one quarter of that in the United States of America, though India has about 20 million more cattle of milking age (Brochure of the marketing of milk in the Indian Union, 1950).

Breeds of Cattle. There are about 30 distinct breeds of Zebu cattle, of which Sahiwal, Red Sindhi and Gir are the only three breeds that could be called distinct milk breeds. There are about six breeds of buffaloes, all developed for milk production.

Sahiwal. The home of this breed is Punjab. The colour of the animal is red, fawn or roan with or without white markings. This breed is the only one in which females have loose horns. Well kept cows have averaged 6,000 pounds of milk per lactation. The average for the breed is 3,500 pounds per lactation. There is central herd registration for this breed, and the cows accepted for registration must average 3,500 pounds per lactation.

Red Sindhi. The home of this breed is Sind. The colour of the animal is brick red and varies from dun to dark brown occasionally. The bull is usually a little darker than the cow. Well kept cows have yielded on the average 5,000 pounds of milk, and the average for the breed is about 3,000 pounds per lactation. There is central herd registration for this breed, and cows are accepted for registration on the basis of 3,000 pounds of milk per lactation.

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1 Most cows in India are milked after allowing the calves to suck and thus stimulate letting down of milk. Most organized dairies, however, wean calves at birth.

Gir. Home of this breed is the Gir forests of Kathiawar. The colour of the animal is white with dark red or chocolate brown patches. Often they have entire red colour. It has a well proportioned body. Average milk production for well kept animals is about 4,000 pounds per lactation. The average for the breed is about 2,500 pounds per lactation.

Murrah. This is the most important breed of buffaloes in India. The home of this breed is the Eastern Punjab. The colour of the breed is black. The average production for the breed will be about 4,000 pounds per lactation. Well kept animals have averaged as high as 6,000 pounds per lactation. The fat content of the milk is very high. The average fat per cent of the different breeds of buffaloes in India, according to Rangappa (1948), is 8.1 per cent.

Cattle Development Plans. In India, dairy cattle development always has been controlled by Government institutions and agricultural schools and colleges. During the last two or three decades, efforts have been made to improve the productivity of Indian cattle. No single policy for development of better cattle can be formulated for the whole country as the circumstances and needs vary widely.

Earlier there was a definite tendency to breed Zebu cattle for both milk and work, that is, to breed for a dual purpose animal. The Royal Commission in Agriculture and other agencies questioned the soundness of this policy. In later years the tendency has been to develop a few breeds for milk and a few others for work. This, however, involves the problem of disposal of females of the breeds developed for work and the males of the breeds developed for milk.

The present breeding policy of the Indian nation seems to tend towards the development of certain breeds, known for their milk producing ability and adapted to the local conditions in their respective zones. The State will encourage the grading of all cattle to one of these breeds, evolving in a few generations, fairly pure breeds for that locality. This will gradually reduce the number of breeds of cattle that exist in India today. This policy of promoting milk breeds does not put any emphasis on draft needs.

The power needs of an average Indian farmer to cultivate the meagre land is so little, the author feels, that there is no need to develop any specialized draft breed. The male of even the highly specialized milk breed, the author believes, will be able to handle the power needs of the average farmer. Besides, with the gradual introduction of agricultural machinery, the draft requirements of cattle probably will decline. Even today, oil engines to lift water, drive flour mills, run cane crushers, work oil mills, etc. are found in small numbers in the villages. With the completion of the many multi-purpose river projects, electricity will be available in many areas for stationary power. For some time to come, however, traction power on small farms will be expected from cattle, and it is claimed that the dairy breeds will be able to provide it. Thus the emphasis today is to breed both draft and dairy breeds toward milk.

A few years ago dairy experts were much opposed to crossbreeding Indian cattle with imported taurus cattle. Importation of foreign cattle was costly since an individual Indian buyer had to compete for

good dairy bulls with a currency that was of low value compared to the dollar or pound, and he also had to meet the expenses of transportation. Military dairy farms in India during the war undertook several cross-breeding projects. It was found that animals with high taurus blood did not stand the rigors of climate, particularly the heat, and did not possess resistance to common diseases. Crossbreeding is being accepted now in selected areas where better environment can be provided such as around the large cities where fluid milk is in heavy demand. This attitude was expressed in a recent meeting of the Animal Husbandry Wing of the Indian Council of Agricultural Research where they gave consideration to the subject of "The scope and extent to which some of the foreign breeds may be utilized for the grading up of local cattle in certain selected areas or pockets in the Country", (Indian Dairyman, 5:3, P.36).

Allahabad Agricultural Institute Herd

History. The Allahabad Agricultural Institute dairy herd had its beginning in about 1910, when the founder of the Institute, Sam Higginbottom, bought a few milk animals for providing milk to the residents of the campus. From 1910 to about 1920 four different breeds of cattle, Kankrej, Gir, Hariana and Sahiwal were tried. In 1920 another breed, Red Sindhi, was introduced. From 1920 to 1934 these five native breeds remained in the herd, and during the latter part of the period the Red Sindhi was selected for further development. No reasons for the selection of Red Sindhi were reported, but it is suspected that this breed was selected particularly due to its small size and economy. It was felt,

probably, that being a small sized breed the Red Sindhi would be readily accepted in the neighbouring villages for the grading of their nondescript cattle.

Crossbreeding. The crossbreeding project was started in 1924. Crossbreeding has been defined by Lush, J. L. (1945) as the mating of two animals which are both purebred but belong to different breeds. Crossbreeding as it is interpreted in Allahabad Agricultural Institute, is the mating of two animals which are both purebred, one belonging to an Indian breed and the other to a breed of Bos taurus. During the period 1924 to 1934 four European breeds, Holstein-Friesian, Brown Swiss, Guernsey and Jersey were imported. The importations depended on gifts from farmers in America accounting for the importation of different breeds. The size and colour pattern of the Jersey, which are close to those for Red Sindhi, are believed to have influenced the selection. Holstein-Friesian which would have been selected from the point of view of increase in milk production, it is suspected, was discarded due to its low fat per cent in milk.

Hutchinson and Joshi (1937) advocated backcrossing as the only system of breeding crossbred cattle that is likely to be successful in small herds. From 1934 the breeding policy has been one of crossbreeding followed by backcrossing with Red Sindhi. This involved mating Red Sindhi females of low production to taurus bulls, and then breeding the progeny back to Red Sindhi bulls. The crossbred males born were not used in the breeding project. This policy was followed expecting the introduction of genes for high milk production in the crossbred by

the crossing, and the prevention of deterioration of the heat and disease resistance qualities of the Indian cattle by backcrossing to Red Sindhi. This breeding policy was followed to date and a herd of about one hundred milking cows has been maintained continuously. As a result, the present herd has cows with varying proportions of Jersey blood from three fourths down to one thirty secondth. The few crossbred animals with foreign blood other than Jersey were also bred back to Red Sindhi, and the present herd has a few of these.

Red Sindhi. A small herd of pure Red Sindhi was maintained, in addition to the crossbreeding project, to provide breeding bulls for the herd. These pure Red Sindhi bulls were also selected for improving the cattle in areas around the Institute, and to improve this breed of cattle in the Institute herds. This suggests the recognition by the Institute of the need to develop certain selected milk breeds of India, without crossing, in areas conducive to their maximum performance.

EARLIER INVESTIGATIONS WITH AGRICULTURAL INSTITUTE HERD AND OBJECTIVES OF THIS INVESTIGATION

Since 1934 the Allahabad Agricultural Institute has continued projects of breeding for improvement within the Red Sindhi breed and crossbreeding between Red Sindhi and Jersey cattle. It was considered desirable to evaluate the results of these projects.

Estimation of Genetic Changes in the Red Sindhi Herd

Stonaker (1952) studied the genetic changes in the Red Sindhi herd from 1934 to the present day estimating probable genetic gain and the heritabilities of various traits. He observed that the greater number of daughters sired by the better bulls and the culling of lower producing cows resulted in estimated increases of 0.6 pounds of butterfat per year or about 0.4 per cent of the average production per year.

Evaluation of the Crossbreeding Project

Stonaker, and others (1952) found that crossbreds calved at an earlier age and produced more milk in the first 305 days of their first lactation than the Red Sindhi. These differences were statistically significant. Backcross cattle showed the same trend in comparison with Red Sindhi but to a lesser degree. He found that among the cows completing the first lactation, the proportion of crossbred cows that remained in the herd for six lactations was twice that of Red Sindhi. He estimated from the data on age at first calving and first lactation production that 1/2 Jersey-1/2 Sindhi would exceed the Red Sindhi in the total production for the

number of years cows remain in the herd (life production) by 2.09 times. This ratio for the backcrosses was found to be: 3/4 Jersey-1/4 Sindhi - 1.47; 1/4 Jersey-3/4 Sindhi - 1.38; 1/8 Jersey-7/8 Sindhi - 1.18; and 1/16 Jersey-15/16 Sindhi - 1.25. He concluded, "It appeared as a result of this study that all proportions of Jersey breeding used exceeded the production of the Sindhi, with the amounts decreasing as relationship to either Jersey or Sindhi deviated from 50 per cent".

Rathore, A. (1949) studied the differences in height and weight at birth, and height and weight at several other intervals to three years of age between Red Sindhi and crossbred male and female calves. He reported that mean weights of crossbred females, at all ages studied except at one and four months, exceeded the mean weights of Red Sindhi significantly. Differences found in other heights and weights were not significant.

Evaluation of Selection Practices at Allahabad Agricultural Institute

All females born in the herd have been maintained at least until they completed one lactation. There were very few occasions when this has not been followed since 1934. The cows were selected for the herd on the merit of their first lactation production. Various scales of production were used varying from 2,000 pounds to 3,000 pounds of milk per lactation. The length of the lactation was seldom taken into consideration. The selection pressure varied depending on the number of animals with low production and the number of animals required to be

culled to maintain a herd of about one hundred milking cows. Thus, cows that ought to have been discarded on the merit of their production often have remained in the herd for varying periods of their life. Cows that decreased in performance in later lactations were also removed from the herd. Thus the selection of cows for the herd was based essentially on the first lactation production. It was considered desirable to study the effects of this selection policy and to find to what extent the policy has been sound.

Stonaker, and others (1952) reported that age at first calving played an important part in the total milk production of the crossbred and Red Sindhi cattle. Since age at first calving seldom has been taken into consideration, it was thought desirable to study the influence of this characteristic on life production. Also, since the interval between first and second calving was known by the time it was necessary to select or discard each animal, it was decided to test the relationship, if any, of this characteristic with life production.

The influence of (1) age at first calving, (2) first lactation production and (3) calving interval on life production can be expressed in measurable terms. It was planned to use these measurable relationships, if statistically significant, to design a suitable method for predicting lifetime production of cows. Selection of females for the herd is recognized as one of the most important factors for the improvement of the herd.

REVIEW OF LITERATURE

Inheritance of Milk Production Characters in Dairy Cattle

It has been estimated that several pairs of genes are involved in most of the characteristics of economic importance in plants and animals. 'Student' (1933) studying an experiment of Winter on high and low protein content and high and low oil content of maize estimated that 100 to 300 Mendelian factors were involved in the selection process. Fisher, R. A. (1933) commented on this to indicate that 'Student' had oversimplified the experiment to get these figures. 'Student' (1935) made a more careful study and concluded that the "oil percentage of Winter's maize was conditioned by the presence, or absence, of a number of genes, at least of the order of 20 to 40, possibly 200 to 400".

Lush, J. L. (1945) in his book, Animal Breeding Plans, mentions an interpretation of work of crossbreeding Guernseys and Holsteins as requiring more than ten pairs of genes to explain breed difference in milk yield, and several more pairs to explain breed differences in percentage of fat.

The inheritance of characteristics of economic importance in dairy cattle can be expected to behave in accordance with Mendelian theory. However, it is almost definite that the number of pairs of genes involved are numerous and are subject to modifications of the simple Mendelian behaviour by linkage, crossing over, sex linkage, etc. According to the Mendelian theory both parents are expected to contribute to the inheritance of characteristics.

Castle, W. E. (1919) found as a result of crossbreeding experiments with Holstein dams and Guernsey sires that the first cross offspring in the first lactation exceeded either parent in butter fat production and bettered the intermediate between the purebreds in quantity of milk produced. With the second lactation records the results were a little more striking. Reciprocal crossings (Guernsey dams and Holstein sires) did not give any significant differences. Castle concluded that he does not suspect any sex-linked factors. This study also exhibited so called hybrid vigor.

Gowen, J. W. (1920) claimed as a result of a crossbreeding experiment that both parents contributed to the determination of butter fat percentage.

Gowen, J. W. (1920) as a result of a study of crossbreeding between dairy and beef breeds observed that the inheritance of milk yield appeared to show a partial dominance of the high milk yield to the low milk yield.

Buchanan Smith, A. D. and others (1930), on the other hand, felt that sex-linked factors do play a certain part in the inheritance of milk yield. They studied the inheritance of milk yield in Ayrshire cattle and found a correlation of sire's daughters to sire's sons's daughters to be 0.253, and the correlation of sire's daughters to sire's daughter's daughters to be 0.322. This suggested sex-linkage since, if there was not sex-linkage sons and daughters would be expected to transmit about the same.

Heritability

Lush, J. L. (1945) explains every characteristic as being influenced by both heredity and environment. The genes can not develop the characteristic unless they have the proper environment, and no amount of attention to the environment will cause the characteristic to develop unless the necessary genes are present. If either the genes or the environment are changed, the characteristic which results from their interactions may be changed. Variances caused by heredity are inherited. Lush, J. L. (1940) defined heritability as the fraction of the variance which was caused by differences in heredity.

Tyler, W. J. and E. Hyatt (1947) estimated the heritability of differences in single unselected records of milk, butterfat and the percentage of fat to be 31, 28 and 55 per cent respectively.

Beardsley, J. P. and others (1950) estimated the heritability of butterfat yield to be 27.4 per cent.

Lush, J. L. and F. S. Strauss (1942) analyzing records from Iowa Dairy Herd Improvement Association from 1936 to 1938 estimated that the heritability of differences between milk production based on one record of cows mated to the same sire to be 0.174. This, they explained, indicated that:

> "Chosen on the basis of one record each, two cows will differ in their breeding values about one sixth as much as their records differ, and that one selecting cows for high record should expect to find their breeding values are about one sixth as far above the average of the group from which they were chosen as their records are".

Basis for Selection in a Dairy Herd

Ivar Johansson and Arthur Hansson (1941) found certain relationship between age of the cows at first calving and the length of their following three calving intervals. Increase in calving interval was found associated to increase in age at first calving. The results of a study conducted by them, of relationship between age at first calving and lactation yields, are given below:

Table 1. Age at first calving, months.

Lactation	-31		32-35		36-	
	Av. Yield k.g.	Relative: of max.	Av. Yield k.g.	Relative: of max.	Av. Yield k.g.	Relative of max.
First	143.9	84.2	150.1	89.0	150.4	90.2
Second	154.5	90.4	152.2	90.2	151.5	90.9
Third	168.2	98.4	168.7	100.0	166.7	100.0
Fourth	170.9	100.0	168.7	100.0	164.6	98.7

They observed that after an early first calving the cows started with a low initial record, and attained the maximum production later, measured in lactations. The authors suggested the following explanation for the difference in the lactation performance between early and late calvers:

> "For the youngest first calvers bodily development is the limiting factor in milk production to a larger extent than for the older ones, and the body reserves of nutrients are comparatively small. The first lactation yield of the early calving heifers is therefore low, but owing to continued development of the body their capacity of production increases markedly towards the second calving. The older heifers are well developed and in

> good condition of flesh at the time of calving and therefore they make a good first lactation record, in their case the udder development is the limiting factor. At the second calving these older cows are poorer in flesh than they were at the first calving and the increase in yield is therefore small, if any at all".

The correlation coefficient between age at first calving and mature yield (yield at 7-9 years of age) was 0.001 indicating that age at first calving had no influence on mature yield. They pointed out, however, that this correlation was based on a selected group as the poorer cows went out of the herd before they had an opportunity to show their mature performance. They concluded from this study that "productive capacity of a dairy cow can not be stated as a function of age alone. Except in the case of young first calvers, age in itself is a less powerful cause of variation in milk and fat yield than has been supposed".

Suljgin, P. S. (1941) took data from 4,000 lactations of Yaroslavl cows and studied influence of lactation duration on life production. He found that longer lactation duration had a negative effect when the total milk production for six years was considered. He concluded that best total production is obtained by short service periods, frequent calvings and short lactations.

Gethin, R. H. (1950) in his study of age at first calving on subsequent performance quotes A. Hansson for the suitable age at first calving as, "that for which the cow's total milk and fat production, divided by total food intake, gives the largest quotient". He indicated that provided the conditions are favourable the life time production of early calvers does not fall or falls very little, below that of late calvers in spite of the observation he made that the first lactation yields of

early calvers were smaller than that of late calvers. He determined the life production on a basis of a herd life of 7 or 8 years. He attributed this advantage that the early calvers had in greater life production to longer productive life.

Roth, F. J. (1951) determined the coefficient of correlation between first 200 day yields of the first lactation and life production as measured by five to six recorded years, with the records of the Oldenburg Herdbook Society. The first 200 day lactation accounting for 46 per cent of the variation in the life time yield.

Kliesch, J. and E. Bankwitz (1952) determined the coefficients of correlation between milk yield of the 180 days of the first lactation and life production. The combined yield of the first four lactations was taken as a measure of the life production, in two herds of European cattle. In the black pied low land herd the first 180 days yield accounted for 28 per cent of the variation in the total yield. In the spotted mountain herd this figure was 52.

Chapman, A. B. and G. E. Dickerson (1936) studied the relation of age at first calving to butterfat production in the first five lactations from the records of 253 Holstein cows from 40 herds in Wisconsin. The coefficients of correlation of age at first calving to the first, first two, first three, first four and first five lactations were 0.22, 0.24, 0.22, 0.17 and 0.13 respectively. This, they observed, showed an irregular tendency for production to increase as age at first calving increased. Then they studied the effect of age at first calving to total production to a certain age, 84 months from birth. The cows whose age at

first calving was within the age group 22-23 months had the highest 84 month production, 1,930 pounds of fat. The group with the lowest age at first calving, 18-21 month group, had an average 84 months production of 1,870 pounds of fat, and the group with the highest age at first calving, 36-42 month group, had an average 84 month production of 1,490 pounds of fat. They observed that early calving provides a greater productive life which more than compensates for the lowering of yield in the first few lactations due to lack of maturity.

Larson, C. J. and others (1951) studied the effect of age at first calving and first lactation production on life production measured by 36 to 84 months of life, with Dairy Herd Improvement Association records. They found a coefficient of correlation of 0.57 between first lactation 305 day production and 84 months production, and -0.27 between age at first calving and 84 month production. Both the coefficients were statistically significant. They observed a coefficient of correlation of 0.06 between age at first calving and first lactation 305 day production indicating that these two variables were independent of each other. On the basis of the two variables, age at first calving and first lactation production, they designed a multiple regression to predict 84 month production. They found that the age at first calving and first lactation production combined accounted for 41 per cent of the variances in 84 month production.

EXPERIMENTAL

Sources of Data

Since the Institute wanted to study several breeds before deciding on one Indian and one European breed for future development, the Allahabad Agricultural Institute herd consisted of a number of Indian and European breeds of cattle from 1920 to 1934. Satisfactory records were available on this herd since 1920, although the herd was founded about 1910. By about 1925 the process of maintaining records was fairly well organized. From 1934 the records were made more complete by including information on the weight of cattle in addition to the production data.

Each calf was given a serial number at birth. Two sets of serial numbers were kept, one for the bull calves and one for heifer calves. When a calf reached six months of age a history sheet was prepared for it. From then till the animal was removed from the herd the information required on the history sheet was periodically entered. The following information was available on most animals from the history sheets.

1. Name, number and breed of the animal
2. Date of birth
3. Pedigree of the sire and the production of its dam
4. Pedigree of the dam, production of the dam and grand dam
5. Height at wither at birth, at intervals of one month till six months of age, then at one year and intervals of one year thereafter
6. Weight at birth and at intervals of one month thereafter
7. Veterinary record

8. Age at first calving
9. Production (separately for each lactation)
   Monthly yield: pounds of milk, fat and per cent fat
   Lactation yield: pounds of milk, fat and per cent fat
   Annual yield: pounds of milk
   Days in milk and dry
10. Number of services per conception
11. Name and breed of sire for each conception
12. Date of each conception
13. Date of each calving
14. Sex, height and weight of each calf

Collection of Data

For the purposes of this study records for the years 1925 to 1946 were used. The bulk of the data, however, came from the latter half of the period when there were many more animals in the herd. To supplement information provided by records of the Allahabad Agricultural Institute, records of the Jersey herd at Kansas State College were used. Jersey records were selected since the bulk of the crossbred data from Allahabad related to Jersey and Red Sindhi crosses. Records of the Jersey herd were available for the period 1923 to 1946. Here again the bulk of the data came from the latter half of this period.

The history sheets of all animals that have completed at least one lactation were collected. These were assorted into the different breeds and crossbred groups as Red Sindhi, 1/2 Jersey-1/2 Sindhi, 1/4 Jersey-

3/4 Sindhi, 1/2 Brown Swiss-1/2 Sindhi, 1/4 Brown Swiss-3/4 Sindhi, 1/2 Holstein Friesian-1/2 Sindhi, Murrah buffaloes and Jersey. The few available records on 1/8 Jersey-7/8 Sindhi and few other crossbred groups were not used as the number of cows with total production in these groups were very few. Within each breed or crossbred group the records were arranged according to the year the first lactation was made. Within the classification by years the records were arranged according to the sire of the animal.

The following data were taken from the history sheets for each animal selected for this study. Number of the cow, sire, dam, year of first calving, age at first calving, 305 day production of the first lactation, interval between first and second calving, total milk production in seven years from date of birth, total milk production in ten years from date of birth, and total milk production in five years from date of first calving. Age at first calving was expressed in months. Fractions of a month were corrected to the nearest month. To standardise first lactation production for length of the lactation, all records were corrected to a 305 day basis. This was done by calculating the first 305 days production in case of lactations running more than 305 days. In case of complete lactations with less than 305 days the production of the fewer days was taken as the 305 day production, Winters, L. M. (1948). Incomplete lactations were not included in the study. This standardizing was necessary since in the herd several animals had extended lactations. Correction to 305 day was selected, since the ideal to aim in dairy husbandry management is to have a ten

month lactation followed by two to three months of dry period to give the desirable calving interval of 12 to 13 months, Joshi, D. K. and others (1944).

The interval between first and second calving was expressed in months. Fractions of a month were corrected to the nearest month. For the seven year production from birth all the milk given by a cow from first freshening to the time she completed seven years of life was calculated from the monthly production record of the history sheets. Similarly for ten year production all milk that was given by the cow till she completed ten years of life was calculated. The five year milk production since calving was all milk that was given by the cow during the five years since first calving. The first lactation production, seven year production from birth, ten year production from birth and five year production from first calving were expressed in units of hundred pounds of milk. Fractions of hundred pounds were expressed to the nearest hundred pounds. For instance a cow having a ten year production of 17588 pounds of milk was expressed as 176 hundred pound units. This was done to facilitate calculation work. It was recognized that pounds of milk alone does not measure completely the productive output of the cow. The per cent of fat is also responsible for the energy output. Thus it was recognized that total butterfat production is a better measure of a cow's physiological response to her inherited potentialities for milk secretion, Eldridge, F. E. (1948). In a study of the Allahabad Agricultural Institute herd, Stonaker, and others (1952) found no significant difference in fat per cent of milk between 1/2 Jersey-1/2 Sindhi, 1/4 Jersey-3/4 Sindhi and

1/8 Jersey-7/8 Sindhi when compared with Red Sindhi. Therefore, production was expressed in pounds of milk rather than in pounds of fat since most Indian dairy farms where records are kept express production in pounds of whole milk. It was desired to have results of this study expressed in a measure that can be utilized by most of the dairy farms without the need for any conversion.

Appendix tables 1 to 7 give the original data for the different breed groups.

Selection Basis at the Agricultural Institute

The main basis of selection of cows to be retained in the milking herd has been the first lactation production. However, cows that did well in the first lactation but decreased in production in later lactations were also discarded. At the Allahabad Agricultural Institute various scales of first lactation production were used towards selection of cows for the herd. The one most commonly used was 3,000 pounds of milk in the lactation without correction to a 305 day standard. Immediately after the war there was a heavy shortage of cattle food and this caused the Allahabad Agricultural Institute to dispose of a portion of the herd including a few heifer calves. Probably a few cows were discarded then which otherwise might have stayed in the herd. However, essentially all heifer calves born were maintained till they completed at least one lactation.

From the records of the Allahabad Agricultural Institute herd and the Kansas State College herd, the age at first calving, first lactation

305 day production and interval between first and second calving of all cows that completed at least the first lactation in the herd were taken. This information was broken down by breed and crossbred groups. As the policy essentially had been to study the first lactation production as the criterion to select the cows for retaining in the herd, it was decided to study for this investigation the hereditary characters that are exhibited by the end of the first lactation. The age at first calving, first lactation 305 day production and interval between the first and second calving therefore were selected for this study suspecting that these are connected with the producing ability of a cow. It was recognized that weight of a cow at freshening or at any other particular age may have a certain relationship to her producing ability. However, this factor was not included in this study as weight measurements on all cows that had at least the first lactation in the herd were not available. The average age at first calving, first lactation 305 day production and interval between first and second calving were calculated for the different breed groups with the information from the entire herd. Murrah buffaloes had the highest age at first calving, 47 months, and 1/2 Jersey-1/2 Sindhi the lowest, 29 months. The 1/2 Holstein-1/2 Sindhi had the highest first lactation 305 day production, 6100 pounds, and Red Sindhi the lowest, 2600 pounds. The Murrah buffaloes had the highest interval between first and second calving, 17 months, and the Jersey herd of the Kansas State College had the lowest, 13 months.

Statistical Analysis of the Selection Practices at the Agricultural Institute

The basis of selecting cows in the herd as stated earlier was an arbitrary one and there were occasions when selection practices varied. It was felt necessary to check with the available records how significant the selection had been. The records of all cows that had production figures for seven years from birth were separated and recorded under the heading 'Selected' group. The seven year production was one of the three periods selected to be a measure of total production, and for any cow was the earliest measure of total production. The records of the other cows which had the first lactation in the herd but did not complete at least seven years from birth were grouped under the heading 'Discarded' group. The difference between the 'Selected' group and the 'Discarded' group for the hereditary characters under investigation was expected to give an indication of the actual effect of the attempts to select on the basis of first lactation production.

Age at First Calving as a Basis of Selection. For age at first calving, Red Sindhi, Kansas State College Jersey and 1/4 Jersey-3/4 Sindhi did not show any difference between 'Selected' and 'Discarded' groups. The 'Selected' group of the 1/2 Jersey-1/2 Sindhi and 1/4 Brown Swiss-3/4 Sindhi breeds had a higher age at first calving by three months than the 'Discarded' groups. The 'Selected' groups of 1/2 Brown Swiss-1/2 Sindhi, 1/2 Holstein-1/2 Sindhi and Murrah buffaloes had a lower age at first calving than the 'Discarded' groups. The results are given in Table 2.

The figures were subjected to analysis of variance as shown under

Table 2 according to Snedecor, G. W. (1946), Statistical Methods, Table 11.3 and Dixon and Massey (1950), Introduction to Statistical Analysis, Table 10.17. Using the error mean square, the breed and crossbred group and selection group mean variances were tested for significance.

The F value of breed and crossbred group mean square, 8.76, was highly significant and the F value of Selection group mean square, 1.13, was non significant. Thus the differences between breed and crossbred groups for average age at first calving were statistically non significant. This indicated that age at first calving was not used as a criterion to select cows for the herd, although it is conceivable that a few cows were discarded from the herd due to late maturity.

First Lactation Production as a Basis of Selection. All breed and crossbred groups, excepting 1/2 Brown Swiss-1/2 Sindhi, showed that the 'Selected' group averaged more milk in the first lactation than the 'Discarded' group. The increase ranged from 600 to 1,400 pounds. The 'Selected' group of 1/2 Brown Swiss-1/2 Sindhi showed lower milk yield than the 'Discarded' group by 700 pounds. The grand average of the 'Selected' group was higher in first lactation production by 680 pounds than the 'Discarded' group. The results are given in Table 3.

The figures were subjected to analysis of variance as shown under Table 3. Highly significant differences were found between the breed and crossbred group means indicating real differences between the breed and crossbred groups in first lactation production. The differences between selection groups were found significant. This suggested that the Institute has had a definite policy of selecting animals for the herd on

Table 2. Average age at first calving of the 'Selected' and 'Discarded' groups of cattle

Breed and crossbred groups	Entire herd		Selected group		Discarded group	
	Number of cows	Average months	Number of cows	Average months	Number of cows	Average months
Red Sindhi	82	42	27	42	55	42
1/2 J-1/2 S	30	29	21	30	9	27
1/4 J-3/4 S	69	36	23	36	46	36
1/2 BS-1/2 S	16	42	9	39	7	46
1/4 BS-3/4 S	28	33	9	35	19	32
1/2 H-1/2 S	11	38	10	37	1	46
Murrah	62	47	11	45	51	48
Jersey	91	30	29	30	62	30
		Mean		36.8		38.4

Analysis of variance:

Source of variation	D. F.	Sum of squares	Mean square	F	Significance
Total	15	674			
Breed and crossbred groups	7	595	85.0	8.76	**
Selection groups	1	11	11.0	1.13	N.S.
Individuals (error)	7	68	9.7		

* Probability less than 0.05, Significant
** Probability less than 0.01, Highly significant
N.S. Probability greater than 0.05, Non significant

Table 3. Average first lactation 305 day production of the 'Selected' and 'Discarded' groups of cattle

Breed and crossbred groups	Entire herd		Selected group		Discarded group	
	Number of cows:	Average milk 100 lbs.	Number of cows:	Average milk 100 lbs.	Number of cows:	Average milk 100 lbs.
Red Sindhi	82	26	27	32	55	23
1/2 J-1/2 S	30	45	21	47	9	39
1/4 J-3/4 S	69	34	23	43	46	29
1/2 BS-1/2 S	16	48	9	45	7	52
1/4 BS-3/4 S	28	34	9	42	19	31
1/2 H-1/2 S	11	61	10	61	1	54
Murrah	62	27	11	32	51	26
Jersey	91	57	29	61	62	55
		Mean		45.4		38.6

Analysis of variance:

Source of variation	D. F.	Sum of squares	Mean square	F	Significance
Total	15	2,286			
Breed and crossbred groups	7	1,970	281.4	14.7	**
Selection groups	1	182	182.0	9.5	*
Individuals (error)	7	134	19.1		

* Probability less than 0.05, Significant
** Probability less than 0.01, Highly significant
N.S. Probability greater than 0.05, Non significant

the basis of production in the first lactation.

Interval Between First and Second Calving as a Basis of Selection. Red Sindhi and 1/4 Brown Swiss-3/4 Sindhi did not show any difference between the average interval between first and second calving of the 'Selected' group and the 'Discarded' group. 1/4 Jersey-3/4 Sindhi, 1/2 Brown Swiss-1/2 Sindhi and 1/2 Holstein Friesian-1/2 Sindhi had the average calving interval for the 'Selected' group smaller than that for the 'Discarded' group by one to two months. On the other hand 1/2 Jersey-1/2 Sindhi, Murrah buffaloes and Jersey had the average calving interval for the 'Selected' groups higher than that for the 'Discarded' groups by one to four months. The results are given in Table 4.

The figures were subjected to analysis of variance as shown below Table 4. The different breed and crossbred group means did not show significant differences indicating that between breed and crossbred groups there was no difference in the interval between first and second calving. The two selection group means also did not show any significant differences indicating that the interval between calving was not taken as a criterion to select animals for the herd.

The 't' Test

Analysis of variances of figures of Table 3 indicated that the eight breed and crossbred groups when combined showed real differences between 'Selected' and 'Discarded' groups for the first lactation production. It was decided to test each breed or crossbred group separately for significance

Table 4. Average interval between first and second calving of the 'Selected' and 'Discarded' groups of cattle

Breed and crossbred groups	Entire herd		Selected herd		Discarded herd	
	Number averaged	Average months	Number averaged	Average months	Number averaged	Average months
Red Sindhi	70	16	27	16	43	16
1/2 J-1/2 S	29	14	21	14	8	11
1/4 J-3/4 S	59	16	23	15	36	16
1/2 BS-1/2 S	15	15	9	14	6	16
1/4 BS-3/4 S	26	15	9	15	17	15
1/2 M-1/2 S	11	14	10	14	1	15
Murrah	46	17	11	20	35	16
Jersey	83	13	29	14	54	13
		Mean		15.2		14.8

Analysis of variance:

Source of variation	D. F.	Sum of squares	Mean square	F	Significance
Total	15	54			
Breed and crossbred groups	7	38	5.4	2.57	N.S.
Selection groups	1	1	1	0.48	N.S.
Individuals (error)	7	15	2.1		

* Probability less than 0.05, Significant
** Probability less than 0.01, Highly significant
N.S. Probability greater than 0.05, Non significant

between 'Selected' and 'Discarded' groups for first lactation production using the principle of 't' test, to test equality of means. To use this test it was necessary to find whether within each breed or crossbred group the 'Selected' and 'Discarded' groups showed homogeneity of variances. A simple method to test homogeneity of variances when only two samples are involved (Selected and discarded groups) suggested by Snedecor, G. W. (1946), Statistical Methods, Section 10.13, was utilized. Homogeneity of variances within each breed and crossbred group was established. Then with each of the breed and crossbred groups the 't' test, Snedecor, G. W. (1946), Statistical Methods, Section 4.5, was applied. This test involved the pooling of sums of squares of the two groups to give an estimate of the population variance. From the sample estimate of the population variance the standard error of means was determined. It was found that each of the breed and crossbred groups tested led to the acceptance of the null hypothesis that the two group means represented the same population.

This led to the inference that though the different breeds combined suggested real differences between selected and discarded groups, when studied individually did not show any significant difference between the 'Selected' and 'Discarded' groups, in first lactation production. The small sample size involved in the different breeds might be responsible for this conflicting result. However, the definite trend within most of the breed and crossbred groups indicated that the average milk production of the 'Selected' group exceeded that of the 'Discarded' group. Apparently the selection procedure in the past was in the direction of higher production

in first lactation but other factors were of sufficient magnitude to limit the effectiveness of such attempts.

THE INTER-RELATIONSHIPS BETWEEN AGE AT FIRST CALVING, FIRST LACTATION PRODUCTION AND INTERVAL BETWEEN FIRST AND SECOND CALVINGS

Importance of Inter-relationship

Indian cattle mature late. Therefore, almost all heifers are bred at first heat. The average age at first calving for Red Sindhi was 42 months and for Murrah buffalo was 47 months (Table 2), at the Allahabad Agricultural Institute. In the villages due to malnutrition it is expected that these figures would be still higher. Malnutrition can be attributed as one of the reasons for the delay in maturity. This reason is not considered to be valid at the Allahabad Agricultural Institute herd, however, as the animals were properly fed from birth. From observations at Allahabad it can be said that late maturity is a hereditary characteristic of the Indian breeds. It was found at the Institute that the daughters of indigenous cows bred to European bulls showed early maturity.

With the increasing use of endocrine extracts and preparations for correction of breeding irregularities the possibility of stimulation of Indian cattle to early maturity is being investigated experimentally in some of the Research Institutions in India. The question of the desirability of artificial stimulation to early maturity has to be investigated. There was a suspicion that early maturity in Indian cattle might cause lowering of milk production during early lactation and also might lower breeding efficiency later. This suspicion suggested the desirability of testing the effect of age at first calving on first lactation production

and interval between first and second calving, with the available information from the Agricultural Institute herd and comparing it with the Jersey herd of Kansas State College.

Inter-Relationship Between First Lactation Production and Age at First Calving

The 305 day first lactation production and the age at first calving were obtained for all animals that completed at least one lactation in the herd. These data were recorded by breed and crossbred groups. A simple correlation determination, Snedecor (1946), Statistical Methods, Section 7.2, was run within each breed to determine the relationship between first lactation 305 day production and age at first calving. The coefficient of correlation 'r' for each breed is given in Table 5. Each coefficient of correlation was tested for significance and if the level of probability was more than 0.05 it was considered non-significant.

Table 5. The coefficient of correlation between first lactation production and age at first calving.

Breed and cross-bred groups	Number of pairs of observations	D. F.	'r'	Significance	'r' for P < 0.05
Red Sindhi	82	80	0.064	N.S.	0.215
1/2 J.-1/2 S.	30	28	0.300	N.S.	0.349
1/4 J.-3/4 S.	69	67	0.071	N.S.	0.234
1/2 B.S.-1/2 S.	16	14	0.074	N.S.	0.468
1/4 B.S.-3/4 S.	28	26	0.120	N.S.	0.361
1/2 H.-1/2 S.	11	9	-0.330	N.S.	0.553

Table 5. (Continued)

Breed and cross-bred groups	Number of pairs of obsevations	D. F.	'r'	Significance	'r' for P < 0.05
Murrah	62	60	0.106	N.S.	0.247
Jersey	91	89	0.186	N.S.	0.206

It was found that each breed or crossbred group showed a non-significant relationship between first lactation production and age at first calving. Excepting 1/2 Holstein-1/2 Sindhi all groups gave a positive value for coefficient of correlation ranging from 0.036 to 0.300. It was seen that the ones with high coefficients of correlation were determined from fewer pairs of observations and the ones with greater number of pairs of observations had correlation values about zero, which gave evidence that the first lactation production and age at first calving are independent characteristics.

Inter-Relationship between Calving Interval and Age at First Calving

The interval between first and second calving were recorded for those cows that completed one lactation and at least commenced the second lactation. The age at first calving of these animals also was recorded. These observations were grouped into the different breed or crossbred groups. These pairs of observations were subjected to the simple correlation determination, Snedecor, G. W. (1946), Statistical Methods, Section 7.2. The results are given in Table 6.

Each coefficient of correlation was tested for significance. It was found that within each breed or crossbred group a non-significant relationship existed between age at first calving and interval between first and second calving. However, it was observed that most coefficients of correlation were negative indicating that though the relationship was non-significant there was a tendency for cows calving at a younger age to have the interval between first and second calving a little extended. Excepting 1/4 Brown Swiss-3/4 Sindhi, 1/2 Holstein-1/2 Sindhi and Jersey all cows had a negative correlation ranging from -0.15 to -0.25.

Table 6. The coefficient of correlation between interval between first and second calving and age at first calving.

Breed and cross-bred groups	Number of pairs of observations	D. F.	'r'	Significance	'r' for $P < 0.05$
Red Sindhi	70	68	-0.15	N.S.	0.232
1/2 J.-1/2 S.	29	27	-0.21	N.S.	0.355
1/4 J.-3/4 S.	59	57	-0.22	N.S.	0.252
1/2 B.S.-1/2 S.	15	13	-0.24	N.S.	0.482
1/4 B.S.-3/4 S.	26	24	0.19	N.S.	0.374
1/2 H.-1/2 S.	11	9	0.36	N.S.	0.553
Murrah	46	44	-0.25	N.S.	0.285
Jersey	83	81	0.03	N.S.	0.216

These results indicated that first lactation production and interval between first and second calvings were independent of any significant influence by age at first calving. These findings indicate that early maturity has no adverse effect upon first lactation production or interval between first and second calvings, and therefore work on methods that could be used to induce Indian cattle to early maturity should not be discouraged. Furthermore, independence of these two variables led to the premise that age at first calving and calving interval if correlated with life time production could profitably be added to first lactation production in a multiple regression equation.

LIFE PRODUCTION

Estimation of Life Production

Dairy cows usually do not remain in any commercial herd till the end of their natural life because it is more economical to sell them before they die. This makes it difficult to obtain an accurate measure of longevity in dairy cattle. This difficulty also was faced with the herd of the Allahabad Agricultural Institute. It was necessary, therefore, to establish an arbitrary time limit to be a measure of life production.

For this study three periods were selected; seven years from birth, ten years from birth and five years from first calving. The period five years from first calving was selected to study lifetime production without the confounding effect of early or late maturity. For instance the seven year production and ten year production from birth included the period up to first calving as well and obviously the animal that calved early had a longer productive life compared to the one that calved late. On the other hand in the case of five year production from first calving the length of the productive period was kept constant to five years resulting in an estimate of the average production ability of each animal over an extended period of productive life.

Comparison Between Breed and Crossbred Groups

The seven year production from birth, ten year production from birth and five year production from first calving were recorded for each cow and

grouped by breed and crossbred groups. For each of the three periods within each breed or crossbred group the average production and the standard deviation were then determined. From these observations the coefficient of variation for each figure was obtained. The results are given in Table 7.

It was found that 1/2 Holstein-1/2 Sindhi had the highest average production for the three periods; seven years from birth, ten years from birth and five years from first calving. Murrah buffalo had lowest average production for the periods seven years from birth and ten years from birth closely followed by Red Sindhi. Red Sindhi had the lowest average production for five years from first calving followed closely by Murrah buffalo. The Red Sindhi had the highest coefficient of variation for all three averages indicating a tremendous variation among cows life production. This also indicated that considerable improvement could probably be obtained by selection within the Red Sindhi breed.

Statistical Analysis

It was decided to test for differences among breed and crossbred groups in life production limiting this test to one of three measures of life production. Ten year production from birth was chosen. Ten year production from birth was thought to be more nearly a measure of the life production than seven year production from birth, because it included three more years of the productive life of the cow. The five years production from first calf could not be used as this period did not include the period from birth to first calving which should be considered when judging the

Table 7. The average yield, standard deviation and coefficient of variation for the three measures of life production for the different breed and crossbred groups.

Breed and crossbred groups	Seven year production from birth				Ten year production from birth				Five year production from first calving			
	Number	Pounds of milk	s *	C**	Number	Pounds of milk	s *	C**	Number	Pounds of milk	s *	C**
Red Sindhi	26	11,042	6,062	0.55	17	17,900	8,220	0.46	25	13,948	5,471	0.39
1/2 J-1/2 S	21	18,766	4,462	0.24	14	32,843	4,806	0.15	19	21,380	4,306	0.20
1/4 J-3/4 S	23	15,922	3,917	0.25	14	22,942	4,925	0.22	23	18,130	3,353	0.18
1/2 BS-1/2 S	9	20,155	1,418	0.07	6	35,100	3,253	0.09	9	25,555	4,037	0.16
1/4 BS-3/4 S	9	15,311	3,820	0.25	1	28,700	—	—	9	17,600	2,732	0.16
1/2 H-1/2 S	10	26,230	3,251	0.12	4	41,375	6,954	0.17	9	32,555	4,146	0.13
Murrah	11	9,800	2,406	0.24	8	17,825	2,525	0.16	11	14,118	2,100	0.15
Jersey	29	26,565	5,504	0.21	7	36,200	6,171	0.17	25	28,220	6,140	0.22

* s = Standard deviation.

** C = Coefficient of variation

overall value of a dairy cow.

The ten year production for the seven breed and crossbred groups was subject to analysis of variance, single classification, subsamples with different sample size, Snedecor (1946), Statistical Methods, Section 10.8. The ten year production for the different breed and crossbred groups are given in Appendix Tables 1-7. One-fourth Brown Swiss-3/4 Sindhi was left out as there was only one cow with a ten year production record. The analysis of variance, to test equality of breed and crossbred group means, is given in Table 8.

Table 8. Analysis of variance of ten year production of milk from birth to test equality of breed and crossbred group means.

Source of variation	D.F.	Sum of squares	Mean square	F	Significance
Total	69	676,875			
Breed and crossbred group means	6	458,885	76,481	22.1	**
Cows within breed and crossbred group (error)	63	217,990	3,460		

** Significant at probability less than 0.01, Highly significant.

Using the population variance as the error term, the variance due to breed and crossbred group means was tested for significance. The F value 22.1 was highly significant. This suggested the rejection of the hypothesis that the different breed and crossbred groups represented the same population. The inference was that real differences existed between the breed and crossbred groups in ten year production from birth.

LIFETIME PRODUCTION AS INFLUENCED BY AGE AT FIRST CALVING, FIRST LACTATION PRODUCTION AND INTERVAL BETWEEN FIRST AND SECOND CALVING

Definition of Terms

Earlier sections of this study indicated that differences existed in the herd of Allahabad Agricultural Institute between the different breeds for most of the characteristics studied. The main object of this study, as detailed earlier, was to evaluate the influence of age at first calving, first lactation production and interval between first and second calving on life production within the different breed and crossbred groups. The characteristics involved were assigned the following symbols:

X_1 - Age at first calving in months

X_2 - First lactation, 305 day production in hundred pounds of milk

X_3 - Interval between first and second calving in months

Y_1 - Five year production from first calving in hundred pounds of milk as a measure of life production

Y_2 - Seven year production from birth in hundred pounds of milk as a measure of life production

Y_3 - Ten year production from birth in hundred pounds of milk as a measure of life production

Simple correlation coefficients were determined for X_1, X_2, X_3 with Y_1, Y_2, Y_3 and were recorded separately.

Life Production and Age at First Calving

Simple coefficients of correlation were determined separately for each breed or crossbred group for age at first calving with each of the three estimates of life production. Each coefficient was tested for significance.

The results are given in Table 9.

Table 9. The coefficients of correlation between life production and age at first calving

Breed and Crossbred Groups	Five year production and age at first calving		Seven year production and age at first calving		Ten year production and age at first calving	
	'r'	Significance	'r'	Significance	'r'	Significance
Red Sindhi	-0.425	*	-0.544	**	-0.662	**
1/2 J-1/2 S	0.425	N.S.	-0.095	N.S.	0.235	N.S.
1/4 J-3/4 S	-0.423	*	-0.695	**	-0.688	**
1/2 BS-1/2 S	0.574	N.S.	0.032	**	0.619	N.S.
1/4 BS-3/4 S	-0.762	*	-0.839	**	—	—
1/2 H.-1/2 S	-0.291	N.S.	-0.286	N.S.	-0.564	N.S.
Murrah	0.393	N.S.	-0.790	**	-0.350	N.S.
Jersey	0.317	N.S.	-0.051	N.S.	-0.121	N.S.

* Probability less than 0.05
** Probability less than 0.01
N.S. Probability greater than 0.05 Non-significant

The coefficient of correlation of five year production from first calving and age at first calving gave the estimate of the influence of age at first calving on production without being directly involved in it. Red Sindhi, 1/4 Jersey-3/4 Sindhi and 1/4 Brown Swiss-3/4 Sindhi were the only breed groups that showed significant relationship. All the three showed a negative relationship.

It was observed that Red Sindhi, 1/4 Jersey-3/4 Sindhi, 1/4 Brown Swiss-3/4 Sindhi and Murrah buffalo showed a significant relationship between the

age at first calving and seven year production from birth. All four were negatively related.

Red Sindhi and 1/4 Jersey-3/4 Sindhi were the only two of the breed and crossbred groups that showed a significant relationship between age at first calving and ten year production. In each case this was a negative relationship.

Life Production and First Lactation Production

The influence of the first lactation 305 day production on life production was studied by the simple correlation coefficient determination. Each coefficient was tested for significance. The results are given in Table 10.

Table 10. The coefficients of correlation between life production and first lactation production

Breed and Crossbred Groups	Five Year production		Seven Year production		Ten Year production	
	'r'	Significance	'r'	Significance	'r'	Significance
Red Sindhi	0.799	**	0.773	**	0.855	**
1/2 J-1/2 S	0.478	*	0.260	N.S.	0.402	N.S.
1/4 J-3/4 S	0.316	N.S.	0.220	N.S.	0.020	N.S.
1/2 RS-1/2 S	0.132	N.S.	0.668	*	0.436	N.S.
1/4 RS-3/4 S	0.139	N.S.	0.109	N.S.	—	—
1/2 H-1/2 S	0.235	N.S.	0.568	N.S.	0.534	N.S.
Murrah	0.507	N.S.	-0.415	N.S.	0.300	N.S.

Table 10. (Continued)

Breed and Crossbred Groups	Five year production		Seven year production		Ten year production	
	'r'	Signifi-cance	'r'	Signifi-cance	'r'	Signifi-cance
Jersey	0.809	**	0.736	**	0.907	**

* Probability less than 0.05 N.S. Probability greater than 0.05
** Probability less than 0.01 Non-significant

Red Sindhi, 1/2 Jersey-1/2 Sindhi and Jersey showed a significant relationship between first lactation production and five year production from first calving. In all three cases the relationship was positive and with Red Sindhi and Jersey breeds the correlation coefficient approached $\pm$ 0.8. The five year production measured the producing ability of every cow for a constant productive life and to that extent did not take into account the variation in the total productive life that is normally created because of the differences in age at first calving.

Seven year and ten year periods from birth were measures of the productive life which was affected by age at first calving. Thus the seven year production and ten year production from birth did not estimate only the milk producing capacity for a cow for a particular constant period but also took into account the age at first calving which is a factor that controlled the length of productive life and thereby the total production, of a cow. In commercial dairying they are interested in this combined effect and therefore the relationship between first lactation production and life production was studied as such.

Red Sindhi, 1/2 Brown Swiss-1/2 Sindhi and Jersey showed a significant relationship between the seven year production from birth and first lactation production. This relationship was positive. All other breed and crossbred groups showed a non-significant relationship. Excepting Murrah buffaloes, however, all groups gave positive coefficients of correlation.

Red Sindhi and Jersey gave highly significant positive coefficients of correlation between ten year production and first lactation production. All the other breed and crossbred groups had positive correlation values, though they were non-significant. Red Sindhi and Jersey showed high, positive, significant relationship for the other two estimates of life production as well, showing a reliable relationship between life production and first lactation production.

All the three estimates of life production included the first lactation production as well. This raised the question of the advisability of studying the influence of one characteristic on another when the former is a part of the second factor. The statistical tables used for determining significance of a coefficient of correlation can not be used without modification in determining significance of correlation of two variables, one of which is a component part of the other. The main object of this study was to evaluate the effect of first lactation production on life production which obviously will include the first lactation production. The ten year production which forms a better estimate of life production, on the average will include at least six lactations. The direct effect of first lactation, will be only a fraction and therefore will

influence directly to a smaller extent.

The coefficient of correlation was calculated for the first lactation 305 day production with total ten year production minus the first lactation production. The results are given in Table 11.

Table 11. Coefficient of correlation of ten year production (exclusive of the first 305 day production of the first lactation) and the first lactation 305 day production

Breed and crossbred groups	R.S.	1/2 J- 1/2 S	1/4 J- 3/4 S	1/2 RS- 1/2 S	1/2 H- 1/2 S	Murrah	Jersey
'r'	0.785	0.281	-0.135	0.168	0.414	0.077	0.873
Significance	**	N.S.	N.S.	N.S.	N.S.	N.S.	**

* Probability less than 0.05
** Probability less than 0.01
N.S. Probability greater than 0.05, Non-significant

It was seen that only Red Sindhi and Jersey breeds had a highly significant coefficient of correlation between life production subsequent to first lactation production and first lactation production. This was similar to the trend of relationship that existed between total ten year production and first lactation production as seen in Table 10. However, as was expected, the coefficients of correlation in case of both Red Sindhi and Jersey of ten year production exclusive of the first 305 day production of the first lactation with first lactation production were a little smaller, by 0.07 in the case of Red Sindhi and 0.03 in the case of Jersey, than the coefficients between total ten year production and first lactation production.

In this study one of the major objectives was to evaluate the practice of selecting cows on the basis of first lactation production assuming that first lactation production is an estimate of the total lifetime productive capacity of the cows. Finding that there was no appreciable change in relationship between first lactation production and life production, whether lifetime production included the first 305 day production of the first lactation or not, gave more confidence in further investigations with the life production which includes the first lactation production.

Life Production and Interval between First and Second Calvings

None of the breed and crossbred groups showed any significant relationship between interval between first and second calving and any one of the three estimates of life production. The coefficients of correlation showed a great range of variation and therefore no general comment as to the trend of the association could be made. However, within those breeds with greater number of observations the coefficient of correlation tended to be about 0. The results are given in Table 12.

Discussion

The Allahabad Agricultural Institute breeding policy has not given much consideration to the age at first calving as a factor associated with increase in life production of a cow. It was desired to test the effect of age at first calving on life production. Of the three periods selected to be measures of life production the seven year production and ten year production from birth included a certain length of productive life of the

cow and the period up to the first calving. The proportion of the life which was productive in these cases depended on the age at first calving.

Table 12. Coefficient of correlation between life production and interval between first and second calving

Breed and crossbred groups	Five year production from first calving		Seven year production from birth		Ten year production from birth	
	'r'	Significance	'r'	Significance	'r'	Significance
Red Sindhi	0.115	N.S.	0.131	N.S.	0.098	N.S.
1/2 J-1/2 S	-0.126	N.S.	0.134	N.S.	-0.169	N.S.
1/4 J-3/4 S	-0.031	N.S.	0.088	N.S.	0.022	N.S.
1/2 BS-1/2 S	0.536	N.S.	0.356	N.S.	-0.502	N.S.
1/4 BS-3/4 S	-0.176	N.S.	-0.250	N.S.	—	—
1/2 H-1/2 S	-0.530	N.S.	-0.544	N.S.	-0.820	N.S.
Murrah	0.007	N.S.	-0.126	N.S.	0.028	N.S.
Jersey	0.079	N.S.	0.005	N.S.	0.151	N.S.

N.S. Probability greater than 0.05, Non-significant

On the other hand the five year production from first calving included a definite length of the productive life, which was not affected by the age at first calving directly. The life production of a cow is controlled by the length of the productive life and the producing capacity of the cow. If two cows with the same producing ability had different lengths of productive life, the one with the greater productive life will have a greater

life production. It is conceivable that age at first calving has a definite control on the productive life of a cow because the animal that initiates lactation earlier has a longer period to be in milk production. It was suspected, however, that age at first calving might influence the productive capacity of an animal. If this were true the lengthening of the productive life at the cost of productive capacity may not be desirable.

Red Sindhi, 1/4 Jersey-3/4 Sindhi and 1/4 Brown Swiss-3/4 Sindhi showed significant coefficients of correlation between five year production since first calving and age at first calving. The coefficients were negative ranging from -0.423 to -0.762. Thus early maturity in these breeds caused increase in milk production during the five years from first calving. The five year production from first calving was considered a measure of the productive capacity not affected by any variation in the length of the productive life. This indicated that the inherited and environmental factors that promoted early maturity probably were associated with the inherited and environmental factors that caused increase in milk producing capacity. This was an encouraging finding since it offers the opportunity to work towards early maturity in Indian cattle without any fear of facing an unfavourable result in milk production.

Red Sindhi and 1/4 Jersey-3/4 Sindhi showed a large and statistically significant negative relationship, between ten year production and age at first calving. The coefficient of correlation in either case was higher than that of the coefficient between five year production from first calving. However, strictly such a statement could not be made as the number of observations involved in each case were different. The

coefficient of correlation of ten year production were determined with fewer observations. A greater coefficient of correlation was expected since the ten year production has the combined effect of age at first calving on the productive capacity and productive life of a cow.

Red Sindhi and Jersey showed a highly significant relationship between ten year production from birth and first lactation 305 day production. The coefficient of correlation was positive in either case and was approaching 0.8. This indicated that the factors that increased the first lactation production were associated with those that increased life production. The other five breed and crossbred groups did not show any significant relationship. However, in each case the coefficient of correlation was positive. One-fourth Jersey-3/4 Sindhi had a coefficient of correlation of 0.02 which was rather unexpected as this breed is much nearer to the Red Sindhi type and was expected to take a similar trend.

The interval between first and second calving was not associated with life production. Extended dry periods might be expected to influence the total productive capacity of a cow. Individual cows with such extended dry periods probably did not affect this study as they might have been culled from the herd before they had a chance to make life production records. Thus, this may not be a true measure of the effect of this character.

The study of relationship between the several factors has offered the opportunity of attempting to evaluate the combined use of the factors, age at first calving and first lactation, 305 day production, as estimates of life production.

TESTING REGRESSION OF TEN YEAR PRODUCTION ON AGE AT FIRST CALVING AND FIRST LACTATION PRODUCTION FOR SIMILARITIES WITHIN BREED AND CROSSBRED GROUPS

Evidence of relationship between age at first calving and life production, and between first lactation and life production in a few of the breed and crossbred groups was established in the earlier analysis. Within those breed and crossbred groups that showed significant relationship it was decided to measure the influence of either of the factors, age at first calving and first lactation production on life production. Ten year production from birth was chosen out of the three periods, so far studied, as it was thought that this period was more nearly a measure of the life production of a cow.

Ten Year Production Regressions

The linear regressions of ten year production on age at first calving and first lactation production were determined separately for Red Sindhi, 1/2 Jersey-1/2 Sindhi, 1/4 Jersey-3/4 Sindhi, Murrah buffalo and Jersey. The symbols used in this study were:

X_1 - Age at first calving in months

X_2 - First lactation, 305 day production in hundred pounds of milk

Y - Ten year production in hundred pounds of milk

The simple determination of the regression coefficient 'b' ($b = Sxy/Sx^2$) was made according to Snedecor, G. W. (1946), Statistical Methods, Section 6.5. The results are given in Table 13.

Table 13. Ten year production regression on age at first calving and first lactation production within the different breed and crossbred groups

Breed and crossbred groups	Ten year production in hundred pounds on age at first calving in months			Ten year production in hundred pounds on first lactation production in hundred pounds		
	Number of pairs	'b'	Significance	Number of pairs	'b'	Significance
Red Sindhi	17	-5.13	**	17	4.32	**
1/2 J-1/2 S	14	1.76	N.S.	14	1.96	N.S.
1/4 J-3/4 S	14	-3.77	**	14	0.13	N.S.
1/2 RS-1/2 S	6	2.87	N.S.	6	1.53	N.S.
1/2 H-1/2 S	4	-9.16	N.S.	4	4.00	N.S.
Murrah	8	-1.56	N.S.	8	1.32	N.S.
Jersey	7	-1.57	N.S.	7	5.94	**

* Probability less than 0.05
** Probability less than 0.01
N.S. Probability greater than 0.05, Non-significant.

Red Sindhi was the only breed of all seven breed and crossbred groups to have a highly significant regression on both age at first calving and first lactation production. It was a negative regression on age at first calving and a positive one on first lactation production. According to the results, Red Sindhi showed an increase of 513 pounds of milk in ten year production, over the average for the breed, for every drop of one month from the average, in age at first calving and showed an increase of 432 pounds of milk in ten year production, over the average, for every increase of one hundred pounds, from the average, in the first lactation

production.

One-fourth Jersey-3/4 Sindhi showed a significant regression on age at first calving only and Kansas State College Jersey showed a significant regression on first lactation production only. The 1/4 Jersey-3/4 Sindhi showed an increase of 377 pounds of milk from the average ten year production in the crossbred group for every drop of one month in the age at first calving from the average for that crossbred group. On the other hand Jersey showed an increase of 594 pounds of milk from the average ten year production in the breed for every increase of one hundred pounds of milk in the first lactation production from the average for the breed.

Having established the relationship it was decided to determine an equation to predict ten year production from the two characteristics, age at first calving and first lactation production independent of each other, where ever a significant relationship existed. This determination was made assuming a linear relationship. The method followed was the simple determination of linear regression, Snedecor, G. W. (1946), Statistical Methods, Section 6.5. General equation derived was $\hat{Y} = \bar{y} + b(X - \bar{X})$, where $\hat{Y}$ is the predicted ten year production, $\bar{y}$ is the average ten year production as determined by the investigation, X the independent variates that determined the ten year production, age at first calving or first lactation production and $\bar{X}$ the mean of the independent variates of the investigation, age at first calving and first lactation production of the investigation.

The scatter diagram about the regression line of ten year production as influenced by age at first calving and first lactation production

separately, for Red Sindhi, 1/2 Jersey-1/2 Sindhi, 1/4 Jersey-3/4 Sindhi and Jersey breed and crossbred groups are given in Figs. 1 to 4.

Testing Similarity of Red Sindhi and Jersey Sindhi Crossbred Ten Year Production Regressions

The present herd of the Allahabad Agricultural Institute, on which the results of this investigation will be used consists mostly of Red Sindhi and Jersey Sindhi crossbred cattle. The policy of the Agricultural Institute has been to restrict crossbreeding between Red Sindhi and Jersey. It was therefore decided to combine the information on Red Sindhi, 1/2 Jersey-1/2 Sindhi and 1/4 Jersey-3/4 Sindhi to get a single regression, if this was possible. A statistical technique was employed to determine whether this was justifiable for each of the two variates, age at first calving and first lactation production. This statistical technique involved answering three questions:

1. Do the three groups represent a single population or different populations for age at first calving and for first lactation production after being adjusted for breed means for each character?

2. Do the three regression slopes of ten year production on each of the two determining characters show similarity?

3. Can a common regression line be determined on the breed and crossbred group means for ten year production on each of the determining characters, age at first calving and first lactation production?

The three regression lines of the ten year production of the three breeds on age at first calving and on first lactation production are given

separately in Figures 5 and 6. On each line was marked the mean values for the dependent and independent variates, $\bar{x}_1$ and $\bar{y}$ or $\bar{x}_2$ and $\bar{y}$. The regression line based on the three breed means of ten year production on age at first calving and on first lactation production separately were superimposed in the respective figures.

Test for Adjusted Breed and Crossbred Group Means

General Procedure. The object of the test was to learn whether Red Sindhi, 1/2 Jersey-1/2 Sindhi and 1/4 Jersey-3/4 Sindhi were associated with the differences in ten year production as conditioned by either of the two independent variables, age at first calving and first lactation production. The evidence that there was definite difference in ten year production was established in an earlier analysis under this investigation. It was recognized that the difference between the breed and crossbred groups in ten year production might have been conditioned by the differences in the age at first calving between the three groups or similarly by the differences in the first lactation production. For instance Red Sindhi was shown to have a lower ten year production than the 1/2 Jersey-1/2 Sindhi. It was also shown that Red Sindhi had a lower first lactation production than 1/2 Jersey-1/2 Sindhi. The low ten year production in Red Sindhi and the high ten year production in the 1/2 Jersey-1/2 Sindhi might be associated in a regular fashion to the low first lactation or high first lactation production. Whether there is any such regular association can be tested by adjusting the independent variable, in this case the first lactation production, to a common figure,

that is the mean, and then comparing the ten year production. The effect of this adjustment was then studied by the test of significance of differences among adjusted breed and crossbred group means, Snedecor, G. W. (1946), Statistical Methods, Section 12.3. The sources of variation in this analysis were due to (1) differences between breed and crossbred group means and (2) deviation within breeds about their mean.

Ten Year Production Adjusted to Age at First Calving. Table 14 gives the sum of squares of deviation about the mean of age at first calving, ten year production and sum of cross products for the three breed and crossbred groups separately. The sum of squares of errors of estimate from the regression of ten year production on age at first calving are also given separately. The coefficient of correlation and regression coefficient determined are also given for each.

The figures were subjected to test of significance of adjusted breed and crossbred group means as shown under Table 14. The F value obtained as a ratio between breed and crossbred group mean square and within breed and crossbred group mean square, 10.89 was statistically highly significant. The hypothesis that the three breed and crossbred groups after being adjusted for differences in age at first calving represented the same population for ten year production was rejected. This led to the conclusion that the ten year production between the three breed and crossbred groups differed significantly even after being adjusted for the differences in the age at first calving.

Table 14. Regression and correlation data in the three breed and crossbred groups for ten year production on age at first calving.

Breed and crossbred groups	D.F.	Sum of squares and cross products			'r'	'b'	Errors of Estimate	
		Sx^2	Sxy	Sy^2			S.S.	D.F.
Red Sindhi	16	1800	-9228	108106	-0.66	-5.13	60797	15
1/2 J-1/2 S	13	533	940	30032	0.24	1.76	28374	12
1/4 J-3/4 S	13	1047	-3951	31535	-0.69	-3.77	16625	12
Sum	42	3380	-12239	169673			105796	39

S.S. of errors of estimate = $Sy^2 - (Sxy)^2 / Sx^2$.

Test of significance of adjusted breed and crossbred group means

Source of Variation	D.F.	Sum of squares and cross products			Errors of estimate		
	D.F.	Sx^2	Sxy	Sy^2	S.S.	D.F.	Mean square
Total	44	4499	-26153	343907	191946	43	
Between breed and crossbred group means	2	1119	-13914	174234			
Within breed and crossbred groups	42	3380	-12239	169673	125356	41	3057
			By difference		66590	2	33295
		F =	33295/3057 =	10.89 **			

S.S. of errors of estimate = $Sy^2 - (Sxy)^2/Sx^2$.
** Probability less than 0.01.

Table 15. Regression and correlation data in the three breed and crossbred groups for ten year production on first lactation production

Breed and crossbred groups	D.F.	Sum of squares and			'r'	'b'	Errors of Estimate	
		Sx^2	Sxy	Sy^2			S.S.	D.F.
Red Sindhi	16	4242	18311	108106	0.855	4.32	29065	15
1/2 J-1/2 S	13	1267	2483	30032	0.402	1.96	25165	12
1/4 J-3/4 S	13	774	101	31535	0.020	0.13	31522	12
Sum	42	6283	20895	169673			85752	39

S.S. of errors of estimate = $Sy^2 - (Sxy)^2/Sx^2$

Test of significance of adjusted breed and crossbred group means

Source of variation	D.F.	Sum of squares and cross products			Errors of estimate		
		Sx^2	Sxy	Sy^2	S.S.	D.F.	Mean square
Total	44	8525	38975	343907	165719	43	
Between breed and crossbred group means	2	2242	18080	174234			
Within breed and crossbred groups	42	6283	20895	169673	100184	41	2444
		By difference			65535	2	32768
		F = 32768/2444 = 13.41 **					

S.S. of errors of estimate = $Sy^2 - (Sxy)^2 / Sx^2$
** Probability less than 0.01

Ten Year Production Adjusted to First Lactation Production. Ten year production adjusted to first lactation production was analyzed in the same manner in Table 15. The F value obtained was 13.41. This was highly significant. The hypothesis that the three breed and crossbred groups after being adjusted for differences in first lactation production represented the same population for ten year production was rejected. This led to the conclusion that the ten year production for the three breed and crossbred groups differed significantly even after being adjusted for the differences in the first lactation.

Test for a Common Regression Line

General Procedure. Two questions remained to be answered. (1) Do the three different regression lines have a common slope? and (2) Could a common regression line be used for each of the effects? These two questions were answered through the analysis of errors of estimate from regression of ten year production on age at first calving and first lactation production separately (Analysis of covariance).

The analysis of covariance was applied and tested according to Snedecor, G. W. (1946), Statistical Methods, Section 12.5 and Dixon and Massey (1951), Introduction to Statistical Analysis, Section 12.5, to the ten year production on age at first calving and first lactation production separately. The procedure involved the splitting of total sum of squares of errors of estimate, S_T, to four components S_1, S_2, S_3 and S_4.

To study whether the slopes of the regression lines of the three breeds were similar, the mean square of S_2 was to be tested against mean square of S_1 for F value.

To study whether a common regression line can be used the mean square of $S_2 + S_3 + S_4$ was to be tested against the mean square of S_1 for F value.

Ten Year Production on Age at First Calving. The analysis of errors of estimate from regression of ten year production on age at first calving is given in Table 16. The F value 3.60 just statistically significant at probability less than 0.05 left doubt concerning the differences among the regression slopes.

The test for common regression line discussed earlier was applied. The F value obtained 7.94 was highly significant indicating that a single common regression line should not be used for the regression of ten year production on age at first calving for the three breed and crossbred groups; Red Sindhi, 1/2 Jersey-1/2 Sindhi and 1/4 Jersey-3/4 Sindhi.

Ten Year Production on First Lactation Production. The analysis of errors of estimate from regression of ten year production on first lactation production are given in Table 17.

The test to find whether the three regression lines have similar slopes was applied first. The F value 3.28 was just significant at probability less than 0.05. This was not taken as evidence of differences in the slopes of the three regression lines.

The F value obtained in the test for the common regression line was 9.09, highly significant. This gave evidence that a single regression line should not be used as a common regression line for the

Table 16. Analysis of errors of estimate from regression of ten year production on age at first calving

Source of variation	D.F.	Sum of squares	Component of total S.S.	Mean square
Total	43	191946	S_T	
Breed mean regressions	1	1223	S_3	1223
Average regression within breeds	41	125356	$S_1 + S_2$	3057
Deviation within individual breed regressions	39	105796	S_1	2713
Differences among breed regressions	2	19560	S_2	9780
Remainder - Difference between within breed and among breed regressions	1	65367	S_4	65367

Test for similarity of regression slopes

$$F = 9780 / 2713 = 3.60 *$$

Test for common regression line

$$F = 21538 / 2713 = 7.94 **$$

* Probability less than 0.05
** Probability less than 0.01

Table 17. Analysis of errors of estimate from regression of ten year production on first lactation production

Source of variation	D.F.	Sum of squares	Component of total S.S.	Mean square
Total	43	165719	S_T	
Breed mean regressions	1	28433	S_3	28433
Average regression within breeds	41	100184	$S_1 + S_2$	2444
Deviation within individual breed regressions	39	85752	S_1	2199
Differences among breed regressions	2	14432	S_2	7216
Remainder - Difference between within breed and among breed regressions	1	37102	S_4	37102

Test for similarity of regression slopes

$$F = 7216 / 2199 = 3.28 *$$

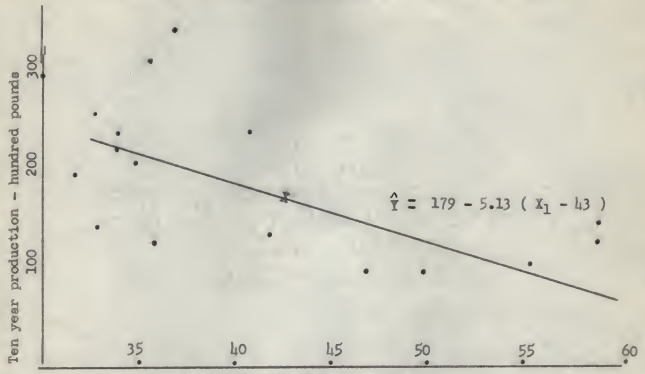
Test for common regression line

$$F = 19992 / 2199 = 9.09 **$$

* Probability less than 0.05
** Probability less than 0.01

three regressions of ten year production on first lactation production.

Figure 1. Ten year production regressions - Red Sindhi.



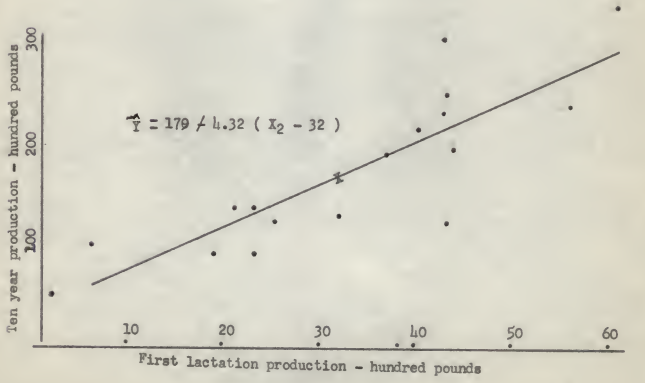
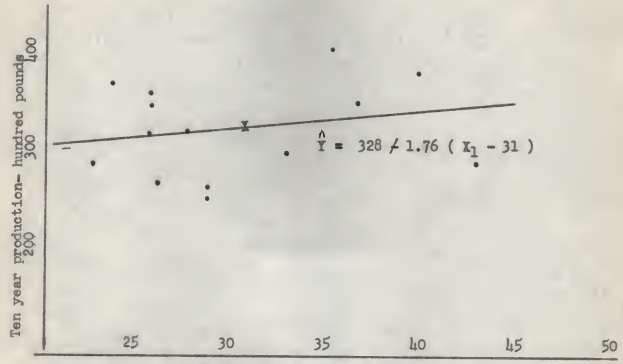


Figure 2. Ten year production regressions - 1/2 Jersey 1/2 Sindhi.



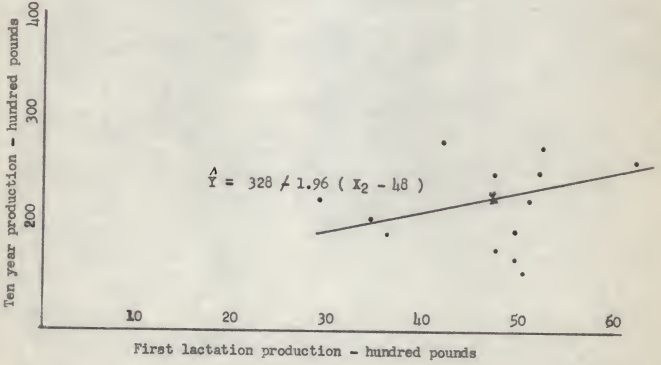
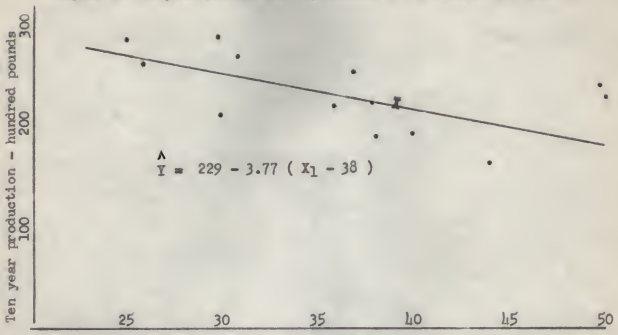


Figure 3. Ten year production regressions - 1/4 Jersey 3/4 Sindhi.



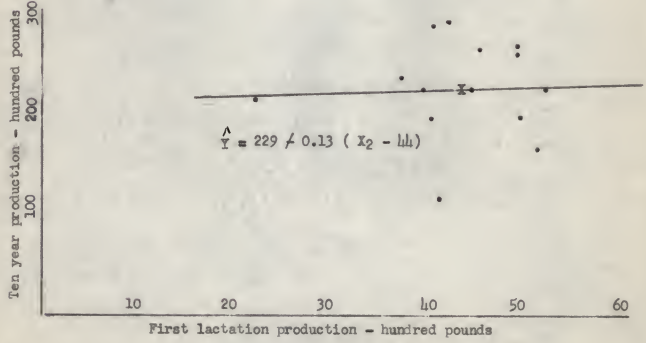
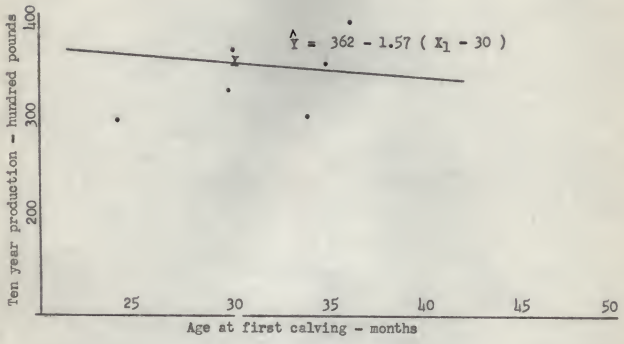


Figure 4. Ten year production regressions - Jersey.



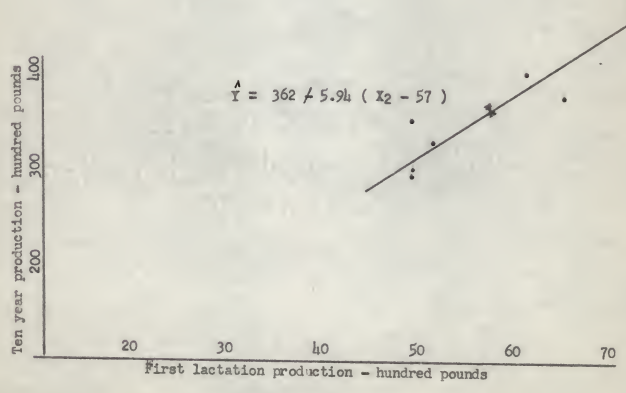


Figure 5. Ten year production regressions on age at first calving for three breeds.

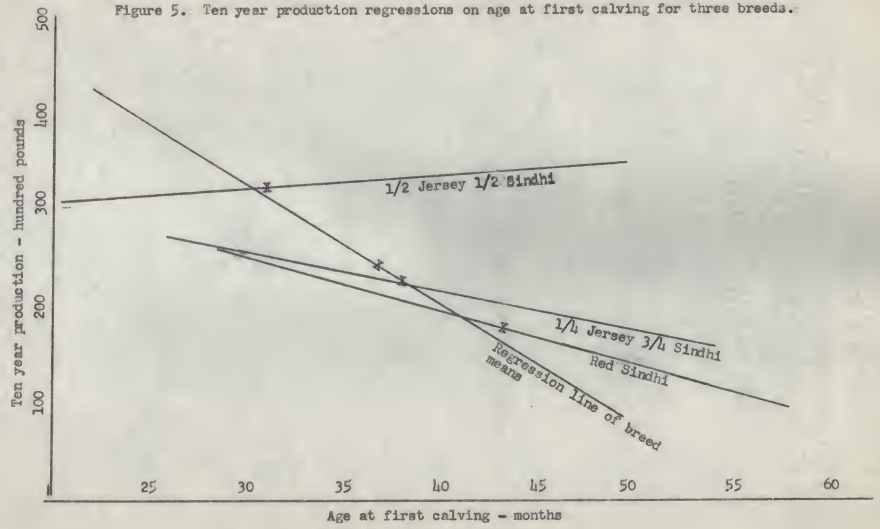
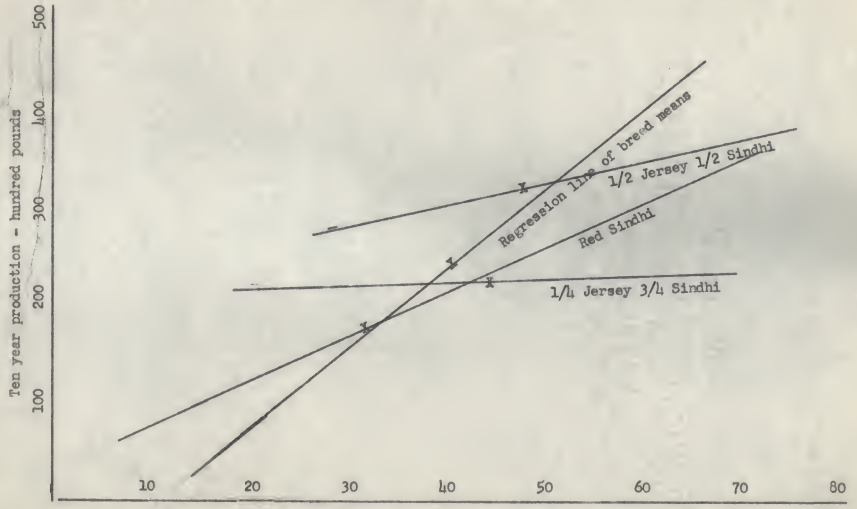


Figure 6. Ten year production regressions on first lactation production for three breeds.



PREDICTION EQUATION FOR LIFETIME PRODUCTION COMBINING AGE AT FIRST CALVING AND FIRST LACTATION PRODUCTION

The results of the previous section indicated that the three different breed and crossbred groups could not be pooled to represent one population. This made it necessary to study each breed or crossbred group separately. The previous sections established the relationship of ten year production with age at first calving and first lactation production. These relationships were used to design an equation for predicting ten year production using the age at first calving and/or first lactation production.

Regression equations are mathematical statements based on the tendency of one variable to be influenced by another. The worth of such an equation is dependent upon the extent to which the dependent variable is influenced by the independent variable. If there is no statistically significant correlation between dependent and independent variables, that is, if the correlation appears to be fortuitous instead of a reflection of a fundamental relationship, a regression equation is valueless. Therefore, equations were developed for Red Sindhi, 1/4 Jersey-3/4 Sindhi and Kansas State College Jersey and none was attempted for 1/2 Jersey-1/2 Sindhi, 1/2 Brown Swiss-1/2 Sindhi, 1/2 Holstein-1/2 Sindhi and Murrah buffaloes (Table 13).

Jersey

The Jersey showed significant relationship between ten year production

and first lactation production, the relationship between ten year production and age at first calving being non-significant. This non-significant relationship with age at first calving was expected as the age at first calving in European cattle is a factor controlled by management practices to a greater extent than by heredity.

The simple regression equation of ten year production on first lactation production was determined as

$$\hat{Y} = 362 \pm 5.94 (X_2 - 57)$$

$$\hat{Y} = 23.4 \pm 5.94 X_2$$

where X_2 is the first lactation production in hundred pounds of milk to be used for predicting ten year production and $\hat{Y}$ the predicted ten year production in hundred pounds of milk. The simple correlation coefficient determined in this study was 0.907.

One-fourth Jersey-Three-fourths Sindhi

This crossbred group showed significant relationship between ten year production and age at first calving, the relationship between ten ten year production and first lactation production being non significant.

The simple regression equation of ten year production on age at first calving was determined as

$$\hat{Y} = 229 - 3.77 (X_1 - 38)$$

$$\hat{Y} = 372.3 - 3.77 X_1$$

where X_1 is the age at first calving in months used as the predictor and $\hat{Y}$ predicted ten year production in hundred pounds of milk. The simple

coefficient of correlation determined earlier in this study was -0.688.

Red Sindhi

The Red Sindhi showed significant relationship of ten year production with both age at first calving and first lactation production. Therefore, it was necessary to develop an equation to predict ten year production using both age at first calving and first lactation production. This involved the determination of the multiple regression equation. The calculation of the multiple regression equation given by Snedecor, G. W. (1946), Statistical Methods, Section 13.3 was followed. This is the indirect method which uses the simple correlation coefficients of the factors involved. The following symbols were used:

Y - Ten year production in hundred pounds of milk

X_1 - Age at first calving in months

X_2 - First lactation production in pounds of milk

r_{y1} - Coefficient of correlation between Y and X_1, independent of X_2

r_{y2} - Coefficient of correlation between Y and X_2, independent of X_1

r_{12} - Coefficient of correlation between X_1 and X_2, independent of Y

$b'X_{1.2}$ - Standard partial regression of Y on X_1 independent of X_2

$b'X_{2.1}$ - Standard partial regression of Y on X_2 independent of X_1

$$b'X_{1.2} = r_{y1} - r_{y2} \cdot r_{12} \,/\, 1 - r_{12}^2$$

$$b'X_{2.1} = r_{y2} - r_{y1} \,/\, r_{12} \,/\, 1 - r_{12}^2$$

$$Y = \bar{y} + b'X_{1.2} \frac{\sqrt{Sy^2}}{\sqrt{Sx_1^2}} (X_1 - \bar{x}_1) + b'X_{2.1} \frac{\sqrt{Sy^2}}{\sqrt{Sx_2^2}} (X_2 - \bar{x}_2)$$

Substituting the values obtained in the regression studies with Red Sindhi,

$$r_{y1} = -0.662; \qquad r_{y2} = 0.885; \qquad r_{12} = -0.599$$

$$b'Y_{1.2} = -0.234; \quad b'Y_{2.1} = 0.714;$$

$$Y = 179 - 0.234 \cdot 328.4/42.4 (X_1 - 43) + 0.714 \cdot 328.4/65.1 (X_2 - 32)$$

$$= 142 - 1.81 X_1 + 3.62 X_2$$

The multiple correlation coefficient R was calculated from the partial regression coefficients obtained earlier in this study, using the formula $R^2 = r_{y1} \cdot b'Y_{1.2} + r_{y2} \cdot b'Y_{2.1}$. The Red Sindhi gave an R value of 0.869 which was highly significant. The simple coefficients of correlation of ten year production on age at first calving and first lactation production were -0.662 and 0.885 respectively.

Discussion and Application of Results

It was possible to determine an equation to predict ten year production using age at first calving and/or first lactation production for only three of the breeds studied, Red Sindhi, 1/4 Jersey-3/4 Sindhi and Kansas State College Jersey.

The equation for Red Sindhi accounted for 76 per cent of the variance among the ten year production average to be due to variance in the age at first calving and first lactation production.

The equation for 1/4 Jersey-3/4 Sindhi accounted for 47 per cent of the variance among the ten year production average to be due to variance

in the age at first calving.

The equation for Kansas State College Jersey accounted for 82 per cent of the variance among the ten year production average to be due to variance in the first lactation production.

This study gave evidence of influence of age at first calving and first lactation production in dairy cattle. The influence of age at first calving was very marked in Red Sindhi and the European crossbred cattle with a greater percentage of Red Sindhi blood. This tends to indicate that in the native cattle the age at first calving has more influence on life production than with European cattle.

Thus while this study approved the importance previously given to first lactation production as a factor for selection in the Agricultural Institute herd, it stressed the need to give attention to age at first calving, as well, as a factor controlling life production.

It was realized that in this study sire effects and environmental effects, particularly the differences due to years were not taken into consideration. Corrections could not be made due to the very few number of cows with ten year production records. These few animals could not be separated into sire and year groups. However, to have some inference of this effect the Red Sindhi herd with life production was broken down to the sire groups and the intra sire correlation of life production with age at first calving and first lactation production was studied. There were five groups as indicated in Table 18.

Table 18. Sire groups and the relationship of ten year production with age at first calving and first lactation production

Sire group	Age at first calving X_1 months	First Lactation X_2 hundred pounds	Ten year production Y hundred pounds
G. S.	54	15	96
99	36	44	247
134	38	36	190
87	29	30	161
140	59	30	161
	$\bar{x}_1$ 43	$\bar{X}_2$ 31	$\bar{Y}$ 171

Intra sire correlation of ten year production and age at first calving was -0.529 comparing to -0.662 for the herd without accounting for sire effect. Intra sire correlation of ten year production and the first lactation production was 0.991 comparing to 0.855 for the herd without accounting for sire effect. The multiple correlation of ten year production with both these factors was 0.991 comparing to 0.869 for the whole herd. This indicated that even after accounting for the influence of sire the definite tendency for a negative relationship between life production and age at first calving and a highly positive relationship between life production and first lactation production was there.

The present herd of the Allahabad Agricultural Institute has a greater part of the herd composed of Red Sindhi and crosses of Red Sindhi

with Jersey, the Jersey blood in most cases being less than 50 per cent. The results of this study, therefore, can be applied to this herd by the use of Red Sindhi equation for the Red Sindhi herd and the 1/4 Jersey-3/4 Sindhi equation for the Red Sindhi and Jersey crossbred herd having less than 50 per cent of Jersey blood.

It was recognized that this study established only the phenotypic relationship of life production with age at first calving and first lactation production. The phenotypic relationship should not be confused with the genetic relationship since the phenotypic relationship accounts for environmental effects in the characteristics studied in addition to the genetic effects. This stresses the need to study genetic relationship between these factors so that the influence of dams on the life production of their daughters can be established.

SUMMARY

The objective of this study was to evaluate the influence of age at first calving, first 305 day production in the first lactation and interval between first and second calving on the lifetime production of a cow. Three periods, seven year production from birth, ten year production from birth and five year production from first calving were chosen as estimates of lifetime production of a cow. A suitable method for selection of cows for the herd could be designed based on the relationships existing among the various factors.

Age at first calving, first lactation production and interval between first and second calving were not significantly correlated, apparently independent within limits of these samples.

Of the seven breed and crossbred groups studied, the Red Sindhi, 1/4 Jersey-3/4 Sindhi, and 1/4 Brown Swiss-3/4 Sindhi showed significant negative coefficient of correlation between five year production since first calving and age at first calving. This relationship indicated that early maturity, contrary to the author's suspicion, was associated with increased milk production in these cattle.

Ten year production was considered a more desirable estimate of lifetime production. Red Sindhi and 1/4 Jersey-3/4 Sindhi showed a large and significant negative relationship between ten year production and age at first calving. Red Sindhi and Jersey showed a highly significant positive relationship between ten year production and first lactation production. No significant relationship existed between interval

between first and second calving and ten year production in any of the breed and crossbred groups.

The regression slopes of ten year production on first lactation and age at first calving for Red Sindhi, 1/2 Jersey-1/2 Sindhi, and 1/4 Jersey-3/4 Sindhi were examined statistically to determine whether they could be combined in order to use a common regression slope. The results indicated that the association of ten year production with age at first calving and first lactation production was significantly different for the Red Sindhi and Jersey Sindhi crossbreds and that a single regression slope could not be used.

Using the relationship of ten year production with age at first calving and first lactation production, equations were developed for predicting ten year production of Red Sindhi, 1/4 Jersey-3/4 Sindhi and Kansas State College Jersey cattle. With Red Sindhi it was advantageous to develop a multiple regression equation since both variables, age at first calving and first lactation production were associated with ten year production. With 1/4 Jersey-3/4 Sindhi and Jersey simple regression equations were developed. No equations were developed for the other breed and crossbred groups because of the non-significant association between the ten year production and either of the two variables. The equations developed are given below:

Red Sindhi	$\hat{Y} = 1142 - 1.81\ X_1 + 3.62\ X_2$.,	$R = 0.869$.
1/4 Jersey-3/4 Sindhi	$\hat{Y} = 372.3 - 3.77\ X_1$.,	$r = -0.688$.
K.S.C. Jersey	$\hat{Y} = 23.4 + 5.94\ X_2$.,	$r = 0.907$.

where $\hat{Y}$ is predicted ten year production in hundred pounds of milk, X_1 is age at first calving in months and X_2 is first lactation 305 day production in hundred pounds of milk.

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A P P E N D I X

Table I. Original data - Red Sindhi.

Cow number	Year of first calving	Sire number	Age at first calving - Mths. X_1	305 day production of first lactation - 100 lbs. X_2	First calving interval - Mths. X_3	Five year production after first calving - 100 lbs. Y_1	Seven year production from birth - 100 lbs. Y_2	Ten year production from birth 100 lbs. Y_3	Those used for regression equation
45	1928	G.S.	40	20	18	53	40	-	
44	1929	"	50	18	18	92	-	96	*
51	"	"	47	22	13	78	57	93	*
43	1930	"	63	1	12	51	6	51	*
48	"	"	58	20	14	144	62	145	*
188	1934	?	44	23	16	57	46	-	
306	1937	?	56	5	11	104	44	104	*
395	"	134	34	35	18	168	166	-	
496	"	99	34	39	10	182	143	221	*
526	"	"	41	55	16	197	152	246	*
527	"	"	33	22	11	121	104	142	*
434	1938	134	34	42	12	159	146	240	*
423	"	140	36	22	15	120	93	-	
566	"	112	28	37	12	120	115	-	
559	"	87	36	24	31	123	52	128	*
401	1939	140	59	42	13	123	63	124	*
425	"	134	42	31	12	127	89	139	*
618	"	87	35	33	19	116	106	-	
596	"	99	33	42	20	206	170	255	*
514	1940	87	32	36	13	128	106	194	*
657	"	99	36	42	13	249	204	312	*
732	1944	112	41	39	21	172	234	-	
716	1945	99	35	45	16	182	119	208	*
770	"	"	37	60	19	257	253	345	*
805	1946	448	42	45	20	157	113	-	
859	1947	617	48	35	18	-	89	-	
862	"	"	48	36	22	-	99	-	
		Number	27	27	27	25	26	17	
		Mean	42	32	16	139	110	179	

Table II. Original data - 1/2 Jersey 1/2 Sindhi.

Cow number	Year of first calving	Sire number	Age at first calving- Mths. X_1	305 day production of first lactation- 100 lbs. X_2	First calving interval- Mths. X_3	Five year production after first calving- 100 lbs. Y_1	Seven year production from birth 100 lbs. Y_2	Ten year production from birth 100 lbs. Y_3	Those used for regression equation
79	1931	P.J.	45	52	12	-	171	-	
80	"	"	43	50	16	231	160	294	*
81	"	"	38	66	13	228	227	413	* *
258	1935	"	40	43	11	301	207	387	*
433	1938	"	31	52	14	-	211	-	
435	"	"	33	35	10	147	148	307	*
457	"	"	26	52	13	251	226	325	* *
458	"	"	28	30	13	214	205	327	*
462	"	"	26	48	13	258	252	353	* *
464	"	"	29	50	15	186	167	269	*
474	"	"	24	38	12	164	164	-	
478	"	"	24	53	12	229	223	379	*
480	"	"	23	37	15	160	165	290	* *
476	1939	"	27	48	12	157	148	277	*
495	"	"	25	31	22	203	199	-	
508	"	"	29	50	12	241	232	-	
549	1940	"	23	36	14	171	177	-	
552	"	"	29	51	12	212	205	258	*
574	1941	"	37	53	12	266	207	353	* *
588	"	"	26	63	16	256	247	366	*
860	1946	M2	26	45	22	188	186	-	
		Number	21	21	21	19	21	14	
		Mean	30	47	14	214	197	328	

Table III. Original data - 1/4 Jersey 3/4 Sindhi.

Cow number	Year of first calving	Sire number	Age at first calving- Mths. X_1	305 day production of first lactation - 100 lbs. X_2	First calving interval- Mths. X_3	Five year production after first calving-100 lbs. Y_1	Seven year production from birth- 100 lbs. Y_2	Ten year production from birth- 100 lbs. Y_3	Those used for regression equation
429	1938	83	28	40	11	265	252	-	
483	1939	87	36	40	12	166	140	-	
500	"	"	31	50	13	242	215	272	*
584	1941	99	26	46	18	188	181	267	*
597	"	87	25	41	13	196	190	291	*
625	1942	99	28	48	26	187	179	-	
629	"	87	30	23	16	157	146	217	*
656	1943	99	30	43	14	199	194	297	*
674	"	87	38	41	14	163	139	196	*
685	1944	112	38	31	11	118	110	-	
720	"	83	38	40	14	146	134	227	*
734	"	"	37	50	12	212	210	264	*
764	"	87	34	41	16	185	156	-	
686	1945	112	53	42	12	117	86	118	*
725	"	99	50	53	15	191	136	229	*
728	"	"	50	38	10	203	129	244	*
783	"	"	31	45	19	196	187	-	
736	"	87	44	52	12	164	125	167	*
741	"	"	40	50	18	182	140	199	*
755	"	"	36	45	26	172	139	224	*
848	1946	617	35	42	17	191	186	-	
855	"	"	38	42	14	157	115	-	
840	"	83	40	55	22	173	173	-	
		Number	23	23	23	23	23	14	
		Mean	36	43	15	181	159	229	

Table IV. Original data - Brown Swiss Sindhi crossbreds.

Cow number	Year of first calving	Sire number	Age at first calving- Mths. X_1	305 day production of first lactation- 100 Lbs. X_2	First calving interval- Mths. X_3	Five year production after first calving- 100 Lbs. Y_1	Seven year production from birth 100 Lbs. Y_2	Ten year production from birth 100 Lbs. Y_3
1/2 Brown Swiss 1/2 Sindhi:								
57	1928	F.	30	32	14	214	204	300
59	1929	"	31	35	16	226	183	345
77	1930	"	38	42	11	218	200	-
198	1934	"	41	57	18	315	224	336
202	"	F.	39	60	15	308	217	-
252	1935	"	48	41	13	299	183	354
346	1936	F.	42	43	13	242	206	381
352	1937	F.	42	50	12	231	206	390
362	"	"	40	48	13	247	190	-
		Number	9	9	9	9	9	6
		Mean	39	45	14	256	201	351
1/4 Brown Swiss 3/4 Sindhi:								
465	1938	99	29	47	16	169	163	-
562	"	"	28	41	13	223	206	287
460	1939	134	39	40	13	157	111	-
484	"	87	26	36	11	192	192	-
532	1941	"	37	43	12	154	128	-
570	"	"	30	51	12	211	192	-
761	1945	99	46	40	14	154	140	-
775	1946	97	52	43	18	146	97	-
901	1947	"	31	35	28	178	150	-
		Number	9	9	9	9	9	1
		Mean	35	42	15	176	153	287

Table V. Original data.- 1/2 Holstein 1/2 Sindhi.

Cow number	Year of first calving	Sire number	Age at first calving- Mths. X_1	305 day production of first lactation- 100 Lbs. X_2	First calving interval- Mths. X_3	Five year production after first calving- 100 Lbs. Y_1	Seven year production from birth 100 Lbs. Y_2	Ten year production from birth 100 Lbs. Y_3
90	1931	149	34	71	13	335	277	-
92	"	"	34	72	14	354	309	426
93	"	"	38	76	13	391	312	492
106	"	W.K.	34	55	12	293	239	414
91	1932	149	42	56	13	-	273	-
95	"	"	37	63	16	326	245	-
112	"	W.K.	40	44	14	356	257	-
116	"	"	35	62	13	312	269	-
118	"	"	36	50	14	317	231	-
115	1933	"	43	65	19	246	211	323
		Number	10	10	10	9	10	4
		Mean	37	61	14	326	262	414

Table VI. Original data - Murrah buffaloes.

Cow number	Year of first calving	Sire number	Age at first calving- Mths. X_1	305 day production of first lactation- 100 lbs. X_2	First calving interval- Mths. X_3	Five year production after first calving- 100 lbs. Y_1	Seven year production from birth 100 lbs. Y_2	Ten year production from birth 100 lbs. Y_3
55	1937	S.S.	70	42	22	155	51	-
214	1940	F.L.	52	39	24	153	90	-
217	"	"	47	35	12	153	94	176
233	"	G.	38	29	12	155	105	223
239	1941	B.	47	22	13	129	75	131
241	"	"	48	33	33	128	77	169
263	"	C.	42	22	13	133	133	176
301	1942	89	30	24	22	123	120	187
287	"	"	36	35	24	110	112	158
307	1943	"	37	30	21	130	99	-
306	1944	"	43	38	28	184	122	206
		Number	11	11	11	11	11	8
		Mean	45	32	20	132	98	178

Table VII. Original data - Kansas State College Jersey.

Cow number	Year of first calving	Sire number	Age at first calving- Mths. X_1	305 day production of first lactation- 100 Lbs. X_2	First calving interval- Mths. X_3	Five year production after first calving- 100 Lbs. Y_1	Seven year production from birth 100 Lbs. Y_2	Ten year production from birth 100 Lbs. Y_3
347	1927	VI	34	49	10	241	214	303
352	1929	"	35	49	19	260	199	355
357	1930	"	36	61	13	277	254	400
359	"	IV	30	51	14	208	183	331
366	1931	"	29	77	13	302	287	-
370	"	"	28	48	11	220	212	-
370	1933	VII	30	65	12	289	265	374
373	"	"	25	72	13	300	300	474
374	"	"	24	49	12	241	240	297
375	"	"	24	45	15	171	171	-
378	1934	"	25	56	13	240	240	-
381	1935	VIII	24	44	15	236	235	-
382	"	"	22	47	16	291	292	-
384	1936	IX	26	57	12	243	243	-
390	1937	X	26	75	12	310	307	-
391	"	"	26	68	12	308	303	-
301A	1938	XI	25	23	16	211	210	-
308A	1940	"	31	53	18	292	261	-
328A	1941	XII	30	86	13	361	338	-
347A	1944	"	31	55	13	224	214	-
351A	1945	XV	36	60	12	-	252	-
352A	"	"	29	70	12	351	322	-
354A	"	XVI	29	78	21	404	381	-
366A	"	XVII	37	76	12	402	320	-
359A	1946	XV	33	73	13	301	256	-
360A	"	"	31	76	12	-	358	-
358A	"	"	29	73	12	372	366	-
390A	1947	XIX	30	71	15	-	248	-
372A	1948	"	50	74	12	-	233	-
		Numbers	29	29	29	25	29	7
		Mean	30	61	14	282	266	362

MILK PRODUCTION DURING FIRST LACTATION COUPLED WITH AGE AT FIRST CALVING AS A MEASURE OF PREDICTING LIFETIME PRODUCTION IN RED SINDHI AND RED SINDHI CROSSBRED CATTLE IN INDIA

by

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Milk production during first lactation coupled with age at first calving as a means of predicting lifetime production in Red Sindhi and Red Sindhi crossbred cattle in India

by

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ABSTRACT

The Allahabad Agricultural Institute, Allahabad, India, was founded in 1910. A breed of Indian dairy cattle, Red Sindhi, has been maintained since 1920. Four other breeds of Indian dairy cattle were maintained from 1910 to 1934. About 1925 bulls of four European breeds were imported and a crossbreeding project was started.

About 1934 a definite breeding policy was formulated for the Institute and has been followed to date. This breeding policy can be divided into two main parts: (1) Purebreeding - Selective breeding within the Red Sindhi and (2) Crossbreeding - Mating of Red Sindhi cows of low production to European bulls and backcrossing the female offspring of subsequent generations to Red Sindhi.

All females born in the herd have been maintained at least till they completed one lactation. The data available at this time for each cow included age at first calving, first lactation production and interval between first and second calving. The cows retained for additional lactations were selected on the basis of first lactation production without giving conscious attention to age at first calving and interval between

first and second calving.

The objective of this study was to evaluate the influence of age at first calving, first 305 day production in the first lactation and interval between first and second calving on the life production of a cow. It was planned to design a more suitable method for selection of cows for the herd based on the relationships existing among the various factors.

Records from the Agricultural Institute herd for the period 1925 to 1946 were assorted into groups as Red Sindhi, 1/2 Jersey-1/2 Sindhi, 1/4 Jersey-3/4 Sindhi, 1/2 Brown Swiss-1/2 Sindhi, 1/4 Brown Swiss-3/4 Sindhi, 1/2 Holstein-1/2 Sindhi and Murrah buffaloes. To supplement information provided by these records, the production of the Jersey herd at Kansas State College from 1923 to 1946 were used. The following data on each cow were taken: (1) age at first calving, (2) 305 day production of the first lactation, (3) interval between first and second calving and (4) life production. Three periods were selected arbitrarily as estimates of life production. These were seven years from birth, ten years from birth and five years from first calving.

Using simple coefficients of correlation no significant correlation was found between age at first calving and first lactation production, or between age at first calving and interval between first and second calving. This indicated that these three variables were independent.

By analysis of variance highly significant differences were found between breed and crossbred groups in production from birth to ten years

of age.

The coefficients of correlation were determined between each of the three measures of life production and each of the three variables, age at first calving, first lactation production and interval between first and second calving. These nine coefficients for each of the eight breed and crossbred groups were tested for significance. Red Sindhi, 1/4 Jersey-3/4 Sindhi and 1/4 Brown Swiss-3/4 Sindhi showed significant negative relationship between five year production since first calving and age at first calving. This gave evidence that early maturity, contrary to the author's suspicion, increased milk production in a cow. Red Sindhi and 1/4 Jersey-3/4 Sindhi showed a large and significant negative relationship between ten year production and age at first calving. Red Sindhi and Jersey showed a highly significant positive relationship between ten year production and first lactation production. No significant relationship existed between interval between first and second calving and any measure of life production in any of the breed and crossbred groups.

The regression slopes of ten year production on first lactation and age at first calving for Red Sindhi and two Red Sindhi crossbred groups were examined statistically to determine whether they could be combined in order to use a common regression slope. The results indicated that the association of ten year production with age at first calving and first lactation production was significantly different for the Red Sindhi and Jersey Sindhi crossbreds and that a single regression line could not be used.

Using the relationship of ten year production with age at first calving and first lactation production, equations were developed for predicting ten year production of Red Sindhi, 1/4 Jersey-3/4 Sindhi and Kansas State College Jersey cattle. With Red Sindhi it was advantageous to develop a multiple regression equation since both variables, age at first calving and first lactation production, were associated with ten year production. With 1/4 Jersey-3/4 Sindhi and Jersey simple regression equations were developed. No equations could be justified for the other breed and crossbred groups because of the non-significant association between the ten year production and either of the two variables. The equations developed are given below:

Red Sindhi	$\hat{Y} = 142 - 1.81\ X_1 + 3.62\ X_2$.,	R = 0.869.
1/4 Jersey-3/4 Sindhi	$\hat{Y} = 372.3 - 3.77\ X_1$.,	r = -0.688.
K.S.C. Jersey	$\hat{Y} = 23.4 + 5.94\ X_2$.,	r = 0.907

where $\hat{Y}$ is predicted ten year production in hundred pounds of milk, X_1 is age at first calving in months and X_2 is first lactation 305 day production in hundred pounds of milk.

It was recognised that the prediction equations were developed with records of a small sample of cattle from the entire herd. The Red Sindhi, 1/4 Jersey-3/4 Sindhi and Jersey equations were developed with data from 17, 14 and 7 cows respectively. This could not be avoided since during the twenty year period of study these were the only cows that had completed ten years of their life in the herd. These few animals have been the ones selected for higher producing capacity. The results obtained

from such a highly selected group is to be used for both high and low producers in a herd. Is this justifiable? Even with such highly selected groups, which would be expected to have a low variance in life production, the variables as age at first calving and/or first lactation production accounted for 47, 76 and 82 per cent of the life production variance for each of the 1/4 Jersey-3/4 Sindhi, Red Sindhi and Jersey breed and crossbred groups respectively. If the entire herd could be taken, the life production variance ought to be greater and it would be expected that the variables as age at first calving and first lactation production under such circumstances would account for a greater percentage of the variances in lifetime production. However, the only reliable method to answer this question would be to raise an experimental herd of cows without any selection, to their natural length of life. Such an experiment would be expensive.